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Report on

Chamber Tests with Human Subjects

I. Design and Operation of Chamber

II. Initial [illegible] of Navy Issue Protective Clothing Against [illegible]

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

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NAVY DEPARTMENT

~~Report on~~

(6) Chamber Tests with Human Subjects
I. Design and Operation of Chamber
II. Initial Tests of Navy Issue Protective
Clothing Against H Vapor.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
Washington, D. C.

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TABLE OF CONTENTS

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ABSTRACT

This report ~~is divided into two sections. The first~~ deals with the design, calibration and operation of a chamber for the exposure of human volunteers to the vapors of chemical warfare agents. The construction of the chamber is such that the temperature, relative humidity and concentration of vapor of the chemical warfare agent can be controlled closely over a wide range of conditions.

The second part deals with the testing of Navy issue S-145 impregnated Arnzen protective clothing, protective ointments and masks. Men dressed in water suspension, solvent and solvent + ZnO impregnated clothing have been exposed to H vapor at CT's ranging from 200 to 2500. A series of tests is in progress in which men dressed in the three types of suits have been exposed repeatedly to H vapor at a CT of 1200. No significant difference has been found in the protection afforded by these three types of suits. The effects of leakage of H through the suits : discussed.

The irritancy of S-461 and S-330 Protective Ointment when applied to the face, ears and neck of the men before exposure has been compared. S-330 is far less irritating than S-461.

The rubber of the gas mask face-pieces and connecting tubes absorbed enough H after 12 to 15 exposures to cause conjunctivitis, laryngitis and erythema of the face. The connecting hoses have been encased in impregnated cloth sleeves, and no break has been observed after 16 exposures.

A screening test ~~has been~~ run on the CT's required to cause burns of different degrees of severity on the bare skin of the arm.

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AUTHORIZATION

1. This work was authorized under Project 547/41, "Maintenance, Bureau of Ships," dated 16 December 1940. The problems which were proposed for study were given in Bureau of Ships letter S-S77-2 (Dz), Serial 811 of 17 December 1940.

STATEMENT OF PROBLEM

2. This investigation was undertaken to design, calibrate and study the operation of a gas chamber for the exposure of human volunteers to the vapors of chemical warfare agents, and to evaluate Navy Issue Impregnated Protective Clothing and Masks when exposed to H vapor, and test the irritancy of Protective Ointments.

KNOWN FACTS BEARING ON PROBLEM

3. At present the Navy is issuing single layer protective clothing which requires suitable testing against vesicant vapors on human beings. Newer developments in protective devices also require extensive testing before they can be adopted. Therefore, it is essential to test such items as clothing, masks, ointments, etc. under carefully controlled conditions so that proper evaluation can be made of existing protecting measures, and to test newer developments still in the experimental stages.

4. TDMR #731 from CWS, Edgewood Arsenal, Md. describes chamber tests on subjects protected only by impregnated shorts. Complete protection against H vapor was afforded to the scrotal area by the impregnated shorts whereas burns of casualty severity resulted on other areas of the body from exposure to 315 to 600 mg. min./m^3 (CT).

THEORETICAL CONSIDERATIONS

5. The use of a properly constructed gas chamber for testing protective equipment against chemical warfare agent vapors is the best available method which will most closely simulate actual field trials and yet be operated under conditions which can be controlled critically. The whole body or, by suitable use of proper protection, any area of the body can be used for testing. The temperature, humidity, concentration of vesicant vapor and length of exposure can be varied at will in the chamber so that any type of condition can be achieved. Relatively high temperatures and humidities have been used in the tests actually carried out so far since the human skin is more sensitive to H vapor under these conditions. It can be assumed that if protective devices, such as clothing, prove to be adequate in these tests they will also be adequate under more temperate conditions.

PREVIOUS WORK DONE AT THIS LABORATORY

6. No gas chamber work has been done previously at this Laboratory.

EXPERIMENTAL WORK

I. GAS CHAMBER DESIGN, CALIBRATION AND OPERATION

GENERAL DESCRIPTION

7. The NRL gas chamber consists of a lead-lined room built as an addition to the laboratory building. It is designed as a static chamber, i.e., no air is passed through the chamber during a test, but the air in the chamber is continually circulated and volatilized agent is added as required to maintain the desired concentration. The volume of the chamber is such as to conveniently accommodate a maximum of ten subjects engaged in moderate activity, and construction is according to the following general specifications.

8. Size: Inside dimensions are 10 ft. by 15 ft. and 12 ft. high, giving a volume of 1,800 $ft.^3$ or 50 $m.^3$.

9. Construction: The chamber is of transite covered frame construction insulated with rock wool. The floor is concrete and is provided with a center drain. The ceiling and walls are lined with lead, all joints being soldered.

10. Entrance: Entrance to the chamber is made through an antechamber approximately 5 ft. by 3 ft. and 7 ft. high. Doors of both the inner chamber and the antechamber are 2'6" by 6'8", open outward, and are weatherstripped and gas proof.

11. Observation Window: This window, approximately 12" by 18", is located near the entrance to the antechamber. It is a single pane, double window with a dead air space between.

12. Porch: An open porch of frame construction is built on to the gas chamber and the laboratory as an approach to the chamber entrance. The roof contains two skylight windows for lighting, and an exhaust fan, General Electric Spec. 272905-1, is mounted in the roof near the antechamber door for ventilation.

13. Exhaust System: An exhaust blower, Buffalo Limit Load Conoidal Fan, size #2, single width, Type LL, clockwise, with direct connected 1/2 H.P. 220-volt motor, is mounted in a gas proof compartment in one corner of the chamber. This compartment is approximately 42" by 30" and 36" high, with a door to the outside for access to the blower. A 12" diameter sheet metal duct extends through the compartment wall 2" into the chamber. The duct opening is equipped with a removable sheet metal cover.

14. A sheet metal duct 13" by 10" extends from the blower compartment to above the roof of the chamber. This duct is provided with an adjustable damper and also with a removable copper gauze tray, 4" deep, containing activated carbon as a filter material.

SERVICES

15. Light: A 500-watt, splash-proof, vapor-proof light is mounted on the ceiling in the center of the room. A 60-watt light is mounted on the ceiling of the antechamber and a 25-watt red signal light is mounted just outside the door of the antechamber.

16. Water: Hot and cold water faucets are located on one wall inside the chamber, and a cold water faucet is available on the chamber porch.

17. Air Circulation: Two 16" ventilating fans are mounted near the ceiling on one wall of the chamber. The fans are General Electric Fans, Spec. 272905-1.

18. Heat: Two banks of strip heaters are mounted on the wall below the circulating fans. Each bank of heaters totals 3,000 watts and the individual heaters in each bank are connected in parallel in such a manner that any individual heater may be readily disconnected.

19. A small steam radiator is also provided. This operates on a 10 lb. steam line and is located in a corner of the room.

20. Electric: Four vapor-proof, splash-proof, 110-volt A.C. electrical outlets are uniformly placed on the walls of the chamber.

21. Humidification: A one-half inch steam line operating at approximately 10 lb. pressure is brought into the chamber near one of the circulating fans.

22. Cooling and Dehumidification: Two "chicken wire" cages, each 24" by 8" by 24" high, open at top and bottom, are set in a sheet metal tray 30" by 24" by 4" high having a 1/4" pipe line to the floor drain. These cages are designed to hold chopped ice and are located on top of the exhaust blower compartment. A canvas cover is provided for these ice cages.

23. Communication: A speaker station, Flexiphone Operadio Type ZC, is set on top of the exhaust blower compartment. This station is covered with activated carbon impregnated cloth and is connected to a master station located on the porch next to the observation window.

24. Emergency communication is carried out through a 2" brass "speaking tube" fitted with an impermeable cellophane diaphragm and capped at each end when not in use. This tube runs through the wall of the chamber near the observation window.

25. Plates 1 - 6 show a number of views of the NRL gas chamber and servo to illustrate the design and construction as well as the various facilities as outlined in this section.

CONTROL OF CHAMBER CONDITIONS

26. Since it is generally accepted that vesicant effects of exposure to H vapor are more severe in tropical climates than in temperate climates, temperature and humidity conditions for chamber operation were selected so as to represent average tropical conditions, i.e., 90°F and 65% relative humidity.

27. Temperature: The temperature is recorded and controlled at 90 $\pm$ 0.5°F by means of a Brown two-point recording controlling potentiometer using a calibrated iron-constantin thermocouple. (Plates 5-D and 16-D.)

28. Heat is applied in three ways: (a) by a bank of continuous heaters consisting of three 1,000-watt strip heaters each of which may be disconnected individually (Plate 5-H); (b) by a bank of four 750-watt strip heaters controlled by the Brown potentiometer. The output of these heaters is regulated by a 7.5 KVA Variac and the degree of heat output with the control circuit open is regulated by a 4,000-watt Allen Bradley carbon pile. This intermittent heating circuit is shown in Plates 5-G, 7 and 16. (c) by a steam radiator (Plate 5-J) which is used to maintain temperature overnight and also to supply continuous heat if the output of the strip heaters is insufficient. The radiator is controlled by a solenoid valve to permit operation from the control laboratory. Cooling is accomplished by filling the wire cages (Plate 4-A) with chopped ice before each test.

29. Humidity: Relative humidity in the gas chamber is maintained at 65 $\pm$ 3% and is also controlled and recorded by the Brown recording controlling potentiometer. A second calibrated iron-constantin thermocouple is fitted with a wick and water reservoir and functions as a wet-bulb thermometer (Pl 5-E). Thus wet and dry bulb readings are recorded.

30. Humidification is accomplished by means of a low pressure, approximately 10 lbs., water trapped steam line (Plate 5-K). A solenoid valve in this line is operated through the control potentiometer wet bulb thermocouple, the valve opening and supplying steam to the room when the wet bulb temperature drops below the control point (80°F). This humidification control circuit is shown in Plate 8.

31. Dehumidification is furnished by the chopped ice in the wire cages (Plate 4-A).

32. A typical record of temperature and humidity control obtained by the described procedures during a chamber test is shown in Plate 29.

33. Wind Velocity: Circulation of air in the chamber is obtained by means of two 16" ventilating fans mounted as shown in Plate 5-F. Measurements of

wind velocity with an anemometer at various heights and locations with the chamber empty showed that the velocity ranges from 1 to 4 miles per hour and averages 2.5 m.p.h.

METHODS OF ESTABLISHING H VAPOR CONCENTRATIONS

34. Concentrations of H vapor used in the NRL gas chamber range from 1 microgram per liter to 100 micrograms per liter (0.001 to 0.1 mg./L). Two methods are used for establishing these concentrations.

35. Bead Saturator: For concentrations ranging from 1 to 8 micrograms/L, a bead saturator containing liquid H (Plate 9) is used. The saturator is set up in the control laboratory in a protective metal jacket and operated at any desired temperature (Plate 17-D). Air is passed through the saturator from a Motoair, Type CAA air pump, (1.4 ft.^{3}/min.) at rates varying from 10 to 30 liters per min. depending upon the amount of H vapor to be delivered to the chamber (Plate 16-A). The saturated air is run into the chamber through a heated glass tube to prevent condensation.

36. Flash Distillation: For setting up concentrations ranging from 8 to 100 micrograms/L, a flash distillation system is employed. Plate 10 shows a schematic diagram of the apparatus and Plate 17-A shows the set up in use. A 5-liter, 3-neck, round bottom flask is clamped in an oil bath maintained at 120°C. One neck of the flask is fitted with an air inlet tube and another with a heated glass tube running into the chamber. The third neck is fitted with a graduated dropping burette. Measured volumes of H are dropped into the heated flask from the burette and as the H is vaporized it is carried into the chamber by an air stream (40 liters/min.). The air stream is supplied by the same Motoair pump used for the bead saturator previously described.

METHODS OF ANALYSIS FOR H VAPOR CONCENTRATION

37. Analysis of H vapor concentration in the chamber is carried out continuously during the period of a test. The primary method of analysis employed is that developed by Dr. J. H. Northrop, a NDRC investigator at the Rockefeller Medical Institute. The details of this method as well as the apparatus have been described by Dr. Northrop in OSRD Reports No. 401, Serial No. 183; No. 570, Serial No. 183A; No. 880, Serial No. 367; and No. 1444. The apparatus has been modified in some respects at this Laboratory and Plates 11, 13 and 17 show diagrams and illustrations of it. The following is a brief description of the method as employed at NRL:

38. Northrop Method: Air from the chamber is pulled into an absorption bubbler (Plate 12) at 200 ml./min. by means of a small Haddaway vacuum pump. The flow rate is measured and controlled by a flowmeter-vacuum regulator system. The absorption bubbler contains about 20 ml. of 3% H_2SO_4 solution and is fitted with (a) an overflow trap, (b) a platinum electrode (gauze), (c) a saturated calomel reference electrode, and (d) an automatic burette.

39. The electrode system and the automatic burette are shown schematically in Plates 11 and 13. The burette, which is connected to a reservoir bottle containing the titrating agent, 0.001 to 0.0001 M Br_2 solution, is kept closed during the sample collection period by means of a toggle switch in the continuous titration cycle. At the end of this period the burette is opened by the switch and the collected H vapor titrated with the Br_2 solution. At the endpoint of the titration the potential rise registered on the galvanometer causes the activation of the photocell circuit which closes the burette. The elapsed time between the opening and closing of the burette is a measure of the Br_2 solution used and thus a measure of the H vapor in the sample. This elapsed time as well as the sampling time is recorded on the revolving drum. Plate 28 shows the record obtained during a typical chamber test and Table 11 shows the necessary calculations.

40. The strength of the Br_2 solution used is dependent upon the concentrations of gas in the chamber and is adjusted so as to permit sample collection periods of 4 to 8 minutes. The solution is standardized against known volumes of standard thiodiglycol solution.

41. Using this method of analysis it is possible to obtain from 7 to 15 analyses during the course of a one hour chamber test. The accuracy of the method is indicated in Table I.

42. Hydrolysis Method: The secondary method of analysis used in connection with all NRL chamber tests is the classical method in which the H vapor is hydrolyzed in acetic acid and the resulting ionic chloride is titrated with standard $AgNO_3$ solution. The method is used to measure the overall average concentration of H vapor during a test for comparison with the average values obtained from the continuous Northrop analyses. Plates 14, 15 and 17-E illustrate the apparatus involved.

43. Air from the chamber is drawn through two series connected absorption bubblers of the Vigreaux type (Plate 14) at 200 ml./min. by means of a small Haddaway vacuum pump. Each absorption bubbler contains 8 ml. of 20% acetic acid and they are maintained at 65°C in a water bath. The sample is collected for the entire period of the test at the end of which time the contents of the bubblers are quantitatively transferred to a 250 ml. beaker, made just alkaline to methyl orange with 6N NaOH solution, and evaporated to a volume of 5 ml. on a hot plate. The solution is transferred to the potentiometric titration apparatus shown in Plate 15 and, after acidification with 6N HNO_3, the Cl^- is titrated potentiometrically with standard 0.004 N $AgNO_3$ solution.

44. The accuracy of this method and a comparison with the results obtained by the Northrop method are shown in Table I.

45. In these tests definite concentrations of H vapor in an air stream were established and analyzed by each of the described methods. These concentrations were established by passing a pure, dry air stream at

200 ml./ min. through a Vigreaux bubbler thermostated at 30°C and containing 5 ml. of a solution of liquid H in dibutyl phthalate. The theoretical concentration of H vapor in the effluent air stream was calculated from Raoult's law, knowing the % by wt. of H in the dibutyl phthalate, and the volatility of H at 30°C (1.325 mg. H/L by H. E. Bent).

TABLE I

STANDARDIZATION AND COMPARISON OF ANALYTICAL METHODS

Conc. of H in Dibutyl phthalate (%)	Conc. of H in Air Stream (γ/L) Theoretical (Raoult's Law)	Northrop Method	Northrop Method Average	Hydrolysis Method
1.125	26	24		23.8
		26		
		24		
		25		
		24	24.6	
1.804	41	36		38.0
		36		
		36		
		36		
		37	36.2	
2.583	59	57		54.2
		56		
		54		
		56		
		56		
		55	55.7	
4.715	106	105		99.2
		105		
		104		
		100		
		97		
		100		
		100	101.6	

46. The above table shows that the two methods of analysis agree very well with each other, but both give results slightly lower than the calculated theoretical values. This is believed due to deviation from Raoult's law and also possibly less than 100% efficiency in the Vigreaux bubbler. This good agreement of the methods and the indicated precision of each are good criteria of their reliability.

STANDARDIZATION OF CHAMBER FOR H VAPOR EXPOSURES

47. To secure information as to the best methods of operation of the chamber, to check the effect of variations in operating conditions, and

to familarize the laboratory personnel with the technique of operation, a number of test runs were made. These test runs are described individually.

No. 1 - Increase in CO_2 Concentration

48. Since the NRL gas chamber is a static chamber, no fresh air is supplied during the course of a test. To determine if the increase in CO_2 concentration is physiologically significant under these conditions, ten men, dressed in permeable protective clothing and wearing gas masks, were placed in the chamber for one hour and CO_2 analyses were made at regular intervals. The data obtained are shown in Table II and Plate 18.

TABLE II

CO_2 CONCENTRATION INCREASE DURING CHAMBER TEST

Time	CO_2(%)	O_2 (%)	Time	CO_2(%)	O_2 (%)
1430	-	-	1503	0.27	-
1433	0.00	-	1512	0.36	-
1438	0.12	-	1518	0.40	20.1
1445	0.18	-	1528	0.50	20.0
1453	0.28	-			

49. It may be seen from the above results that no harmful concentration of CO_2 was attained in this test and thus it was considered safe to carry out all tests as static tests.

Nos. 2-3-4 Flash Distillation Temperature

50. To determine the optimum temperature for the flash distillation method of establishing an H vapor concentration, H vapor to give nominal concentrations of 75, 125 and 100 γH/L was run into the empty chamber with the distillation flask maintained at various temperatures. It was considered most desirable to operate the bath at the lowest temperature which would permit establishing a desired concentration in 10 to 20 minutes. Data from this test are given in Table III and Plate 19.

TABLE III

EFFECT OF FLASH DISTILLATION TEMPERATURE

Temperature of Oil Bath (°C)	Air Flow Rate Liters/Min.	Time	Conc. H (γ/L)	Time Required for Establishment of Conc. (Min.)
74	40	1533	0.0	
		1553	15.3	
		1608	25.0	
		1621	43.0	
		1634	52.0	
		1646	59.5	
		1700	62.3	
		1713	66.7	
		1725	69.1	
		1736	69.6	123
		1749	68.7	
		1804	65.9	
94	40	1104	0.0	
		1110	12.5	
		1124	46.8	
		1139	87.3	
		1153	109.0	
		1158	121.8	
		1201	128.1	57
		1204	123.8	
		1207	122.9	
120	40	1031	0.0	
		1038	12.5	
		1053	76.5	
		1108	97.8	37
		1121	93.0	
		1133	92.6	

51. The above results show that with the distillation bath at 120°C a concentration of 100 micrograms H vapor per liter may be set up in about 35 minutes. It was not considered advisable to increase the bath temperature beyond 120°C since H decomposes at 150°C. This concentration of H vapor represented the highest concentration to be used in the chamber and thus 35 minutes should represent the maximum time required for establishing a concentration.

<u>Nos. 5-6-7 Establishment of H Vapor Concentrations by Flash Distillation</u>.

52. To obtain a working curve for estimating the volume of liquid H to flash into the chamber for setting up various vapor concentrations,

several concentrations were set up in the empty chamber. Theoretical (nominal) concentrations were calculated on the basis of the chamber volume of 50 m^3. Data obtained in these tests are given in Table IV.

TABLE IV

ESTABLISHMENT OF H VAPOR CONCENTRATION BY FLASH DISTILLATION
CONDITIONS: OIL BATH AT 120°C; AIR FLOW 40 LITERS/MIN.

H added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)
1.1		1040	0.0
		1053	22.2
	25.0	1106	31.5
		1119	30.9
		1131	29.8
		1144	29.5
		1156	28.8
		1209	27.8
2.2		1432	0.0
		1439	10.1
		1453	41.5
	50.0	1508	52.8
		1520	51.6
		1532	50.8
		1545	48.5
		1557	46.2
		1610	47.6
4.5		1031	0.0
		1038	12.5
		1053	76.5
	100.0	1108	97.8
		1121	93.0
		1133	92.6
		1145	89.9
		1158	97.7
		1212	97.2
		1226	95.3
		1235	90.2
		1248	94.0
		1302	93.1
		1316	92.5
(Exhaust Blower Turned On)		1326	91.0
		1337	68.2
		1347	37.1
		1359	19.7
		1413	14.4

TABLE IV (Cont'd)

H Added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)
		1424	10.5
		1436	8.5
		1449	7.8
		1503	5.9

53. From the above data it may be seen that the analytical concentrations agree quite well with the nominal. The data are shown graphically in Plates 20 and 21.

54. Further information was obtained in this test as to the rate of decrease of H vapor concentration in the chamber due to condensation, leakage, etc. After the maximum concentration had been obtained in one run, analyses were taken for an additional period of one hour. It was found that the rate of decrease, as shown in Plate 20, was quite slow, indicating little condensation or leakage.

55. Data were also obtained in this test as to the efficiency of the exhaust blower in removing vapor from the chamber. After the one hour test period for one concentration of H vapor, the blower was turned on for another hour. Analyses were made during this time and the rate of vapor removal is shown in Plate 20. From this it was concluded that a two hour exhaust period should be sufficient to remove all but traces of vapor from the chamber.

Nos. 8-9-10 Establishment of H Vapor Concentration with Bead Saturator.

56. To obtain a working curve for the bead saturator method of setting up low concentrations of H vapor, tests were made in which air was passed through the saturator into the chamber at various flow rates. Results of these runs are given in Table V and are shown graphically in Plate 22.

TABLE V

ESTABLISHMENT OF H VAPOR CONCENTRATION WITH BEAD SATURATOR CONDITIONS: SATURATOR AT ROOM TEMPERATURE (32°C) - RUN CONTINUOUSLY

Flow Rate of Air Through Saturator (Liters/Min.)	Time	Conc. H (γ/L) Found	Input Rate (γH/L/Min.)	
10	1643	0.0	-	
	1650	1.8	0.26	
	1703	5.1	0.25	
	1715	8.1	0.25	
	1727	11.4	0.27	Av.
	1738	12.7	0.12	0.23
20	1832	0.0	-	
	1838	1.3	0.22	
	1903	10.3	0.36	
	1915	16.8	0.54	Av.
	1928	21.5	0.36	0.37
30	1453	0.0	-	
	1459	1.4	0.23	
	1511	6.2	0.40	
	1517	8.5	0.38	
	1525	12.8	0.36	
	1537	18.6	0.48	Av.
	1550	25.4	0.52	0.40

57. A uniform rate of H vapor input is obtained for each flow rate as shown above, and an input flow rate curve is shown in Plate 23. From this curve it is possible to determine the time necessary to establish a definite vapor concentration in the chamber using any desired flow rate through the saturator.

Nos. 11-12-13 Effect of Impregnated Suits on Establishment and Stability of H Vapor Concentration.

58. Several test runs were made to determine the influence of standard impregnated clothing on the described methods for establishing H vapor concentrations. In these tests 10 suits impregnated with S-145 were hung on clothes lines in the chamber. In Test #11, data for which are shown in Table VI and Plate 24, the H vapor concentration was set up using the flash distillation method, and it was found that the analytical concentration was only 43% of the nominal concentration. Thus it was indicated that the impregnated suits removed 57% of the added H vapor. To check this conclusion, two more runs were made (Nos. 12 and 13) in which H vapor was added to the extent of 157% of the concentration desired. The results of these tests are shown in Table VII and Plate 25.

TABLE VI

EFFECT OF IMPREGNATED SUITS ON ESTABLISHMENT AND STABILITY OF H VAPOR CONCENTRATION

CONDITIONS: Oil Bath at 120°C; Air Flow 40 liters/min.
10 Impregnated Suits Present.

H Added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)
3.4		1016	0.0
		1023	10.4
	75.0	1031	32.0
		1039	30.8
		1047	21.1
		1053	15.1
		1101	11.4
		1109	9.8
		1115	7.7
		1123	6.8
		1131	5.4

TABLE VII

EFFECT OF IMPREGNATED SUITS ON ESTABLISHMENT AND STABILITY OF H VAPOR CONCENTRATION

CONDITIONS: Oil Bath at 120°C; Air Flow 40 Liters/min.
57% Excess H Added; 10 Impregnated Suits Present

H Added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)
1.6		1221	0.0
		1228	9.9
	15.0	1235	18.7
		1242	15.2
		1249	11.1
		1257	8.7
		1304	6.8
		1311	4.8
		1317	4.5
		1324	4.4
		1331	3.2
		1337	3.1
7.9		1421	0.0
		1426	16.5
		1437	59.8
	75.0	1445	64.9

TABLE VII (Cont'd)

H Added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)
		1450	51.8
		1456	36.4
		1504	27.2
		1511	17.5
		1521	11.4
		1528	10.1
		1535	8.2
		1542	7.1
		1555	5.8

59. It may be seen that using a 57% excess of H, good agreement between nominal and analytical concentrations was obtained. Further indications as to the efficiency of the impregnated clothing in removing H vapor is shown by the rapid rate at which the vapor concentration falls off after reaching the maximum value (Plates 24 and 25).

Nos. 14-15-16 Maintenance of H Vapor Concentration with Bead Saturator.

60. Since, as shown in tests Nos. 11, 12 and 13, considerable H vapor is removed from the chamber by impregnated clothing, a method is necessary for maintaining the vapor concentration at a desired value for the duration of a chamber test. Test No. 14 was designed to determine if the bead saturator could be used for this purpose. A nominal concentration of 20 micrograms H/L was established in the chamber containing 10 impregnated suits, and air was then passed through the bead saturator at 20 l./min. into the chamber for one hour. Analyses were made during this period and the data are given in Table VIII and Plate 26.

TABLE VIII

MAINTENANCE OF H VAPOR CONCENTRATION WITH BEAD SATURATOR

CONDITIONS: Oil Bath at 120°C; Air Flow 40 Liters/Min.
57% Excess H Added; 10 Impregnated Suits Present
Bead Saturator at 20 L/Min.

H Added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)
2.1		0940	0.0
		0946	8.6
	20.0	0952	18.8
		0956	18.1
		1006	14.2
		1013	11.6
		1019	9.2
		1026	8.4
		1033	7.9
		1040	8.1
		1047	7.6
		1054	8.0

61. The above data show that the bead saturator is not capable of maintaining a concentration of greater than 8.0 micrograms H/L in the chamber containing 10 impregnated suits. To establish this fact and to secure practice in maintaining a low H concentration, two runs were made at nominal concentrations of 8.3 and 3.3 micrograms H/L using the bead saturator for establishing and maintaining these concentrations. Table IX and Plate 27 give the data obtained in these tests.

TABLE IX

MAINTENANCE OF H VAPOR CONCENTRATION WITH BEAD SATURATOR

CONDITIONS: Oil Bath at 120°C; Air Flow 40 Liters/Min.
57% Excess H Added; 10 Impregnated Suits Present
Bead Saturator at 20 L/Min.

H Added (ml.)	Conc. H (γ/L) (Theor.)	Time	Conc. H (γ/L) (Found)	
0.9		0932	0.0	
		0938	6.0	
	8.3	0945	10.4	
		0952	8.8	
		0959	8.9	
		1006	9.7	
		1013	9.4	
		1020	8.6	
		1027	8.7	
		1033	8.6	
		1040	8.3	
		1047	8.6	Av.
		1053	5.7(?)	8.5
		1243	0.0	
		1245	2.6	
None (Bead Saturator run for 13' at 20 l./min.)	3.3	1257	4.7	
		1308	3.5	
		1319	4.3	
		1330	4.5	
		1340	4.5	
		1351	4.2	
		1402	3.9	Av.
		1413	3.9	4.1

62. The results shown in the above table and in Plate 27 indicate that concentrations up to 8 micrograms H/L may be satisfactorily maintained in the presence of 10 impregnated suits with the bead saturator.

Nos. 17-18-19-20 Maintenance of H Vapor Concentration by Flash Distillation.

63. Since concentrations of H vapor above 8 micrograms/l. cannot be maintained by means of the bead saturator, several test runs were made to determine the possibility of maintaining concentrations from 8 to 100 micrograms H/L by means of the flash distillation system. The procedure used in this method consists of "flashing" small measured quantities of H into the chamber after each analysis of vapor concentration. These quantities of H to be added were estimated on the basis of the results obtained in the previous analysis. Data obtained are shown in Table X.

TABLE X

MAINTENANCE OF H VAPOR CONCENTRATION BY FLASH DISTILLATION

CONDITIONS: Oil Bath at 120°C; Air Flow 40 Liters/Min.
57% Excess H Added; 10 Impregnated Suits Present

Conc. H (γ/L) (Theor.)	H Added (ml.)	Time	Conc. H (γ/L) (Found)	Av.
	0.9	1550	0.0	
	-	1557	11.0	
8.3	-	1604	13.3	
	0.3	1612	7.4	
	0.4	1618	7.0	
	0.3	1625	8.0	
	-	1632	10.8	
	0.2	1639	9.6	
	0.3	1646	7.5	
	0.2	1653	8.2	
	0.1	1700	9.9	
	0.2	1707	7.7	
	-	1714	7.5	8.4
	1.8	1340	0.0	
	-	1343	7.6	
17.0	0.3	1348	17.2	
	0.3	1351	17.8	
	0.2	1355	19.7	
	-	1359	20.9	
	0.1	1404	20.5	
	0.3	1408	17.2	
	0.3	1412	14.7	
	0.2	1416	18.5	
	0.2	1419	18.4	
	0.2	1423	18.3	
	0.2	1427	18.3	
	0.3	1431	17.0	
	0.2	1435	18.3	
	0.2	1439	18.3	
	0.3	1443	17.4	
	-	1448	17.7	18.1
	2.1	1226	0.0	
	-	1233	10.3	
20.0	-	1238	20.8	
	0.5	1242	18.2	
	0.6	1247	15.2	
	0.5	1252	18.3	
	-	1256	20.3	
	-	1300	21.5	

TABLE X (Cont'd)

Conc. H (γ/L) (Theor.)	H Added (ml.)	Time	Conc. H (γ/L) (Found)	Av.
	0.8	1306	17.8	
	0.6	1309	17.1	
	-	1314	22.1	
	-	1318	22.1	
	0.1	1323	19.5	
	0.7	1327	16.8	
	0.8	1331	15.9	
	0.2	1335	19.3	
	-	1339	24.1	19.3
	3.5	1346	0.0	
	-	1349	3.4	
	-	1353	21.7	
33.3	0.5	1358	33.3	
	0.7	1402	32.6	
	0.4	1407	35.6	
	0.5	1411	33.5	
	0.7	1415	32.2	
	0.7	1420	32.6	
	0.7	1424	32.3	
	0.8	1428	31.8	
	0.8	1432	32.4	
	0.5	1437	33.4	
	0.6	1441	33.9	
	0.7	1445	32.7	
	0.7	1449	32.7	
	0.7	1454	33.1	
	-	1458	33.6	33.0

64. As shown in the above table, this method for maintaining a desired concentration causes some variation in concentrations, especially during the first part of the test but, with increasing experience, the operator is able to minimize these variations and obtain an average concentration which agrees well with the desired value. As a result of these tests the method has been considered satisfactory.

OPERATION OF GAS CHAMBER FOR PHYSIOLOGICAL TESTS

65. The purpose of this section of the report is to describe in detail the exact procedure used in operating the NRL Gas Chamber for a physiological test. In addition, a complete log and complete data for a typical run are presented in detail.

Preliminary Operations

66. Lights and circulating fans in the chamber are turned on and the cover is placed over the exhaust blower opening. The steam radiator

which has been on overnight is turned off. If the flash distillation apparatus is to be used, the oil bath heaters are turned on, the Brown recording controlling potentiometer is turned on, and the Northrop Analyzer is turned on and checked for performance.

Temperature and Humidity Adjustment

67. The intermittent temperature control circuit is turned on as is the steam line solonoid switch. After allowing about 15 minutes for equilibrium to be established, the heat input is adjusted by means of the continuous heaters and Allen Bradley Rheostat so as to give optimum control conditions. The ice cages in the chamber are filled with chopped ice (baseball size) and the canvas cover is placed over the full cages. When the subjects enter the chamber for the exposure test, they are directed to take this cover off the cages and replenish the ice which has melted with two buckets of ice which they carry into the chamber with them. The cover is left off during the period of the test.

Establishment of H Vapor Concentration

68. If a concentration of H vapor greater than 8 micrograms H/L is required, the volume of liquid H required for flash distillation into the chamber is determined from the working curve (Plate 21). This amount of H is then run from the burette into the distillation flask and swept into the chamber with air at 40 liters/min.

69. If the concentration of H vapor required is less than 8 micrograms/L, the time and optimum flow rate for operation of the bead saturator is determined from the working curve (Plate 23). Air is then run through the saturator into the chamber at this rate for the determined period of time. As soon as the passage of vapor into the chamber is started, the red signal light is turned on.

Analysis of H Vapor Concentration

70. Analyses of air from the chamber using the Northrop apparatus are started at the same time as the H is introduced into the chamber and are continued throughout the period of the test. As soon as these analyses indicate that the desired concentration of H vapor has been established, the subjects enter the chamber. At this time chamber air is drawn into the Vigreaux bubblers used for collecting the sample to be analyzed by the Hydrolysis Method. This sample is collected for the entire period of the test and analyzed at the conclusion.

Maintenance of H Vapor Concentration

71. Maintenance of the desired H vapor concentration during the test is accomplished by one of the methods previously described.

Exhausting of the Chamber

72. At the conclusion of the chamber test, the lid covering the exhaust blower duct is removed by one of the subjects and, after the subjects have left the chamber, the exhaust blower is turned on and run for two hours.

Final Operations

73. The lights, circulating fan, oil bath heaters, Brown potentiometer, Northrop Analyzer, intermittent and continuous heaters, steam line and red signal light are turned off. The overnight steam radiator is turned on and the chamber left until the next test.

Log of Typical Chamber Test

74. Table XI shows a complete record of the data obtained in a typical chamber test. In addition, Plates 28 and 29 show the temperature and humidity record as well as the analytical record for this test.

TABLE XI

DATA FOR TYPICAL CHAMBER TEST (TEST NO. 36)

1. 10 men in the chamber; 5 clothed in standard S-145 water dispersion impregnated clothing; 5 clothed in standard S-145 tetrachloroethane impregnated clothing.
2. Desired concentration = 20.0 γH/L for one hour (CT=1200).
3. 1.2 ml. H flash distilled into the chamber to establish the concentration, and flash distillation used for maintaining the concentration.

Standardization of Br_2 Solution with Standard Thiodiglycol Solution (1.0 ml. TDG Solution = 88.0 γH)

Min. (from drum recorder) = 88.0 γH

0.86	0.85	0.84	0.86	0.86	
0.89	0.83	0.85	0.90	0.83	Average 0.857

Blank

0.06	0.06	0.07	0.07	Average 0.065

$$\gamma H/min. = \frac{88.0}{(0.857-0.065)} = 111.2$$

TABLE XI (Cont'd)

At 200 ml./min. sampling rate:

$$\gamma H/L = \frac{111.2 \times \text{Titration Time}}{0.200 \times \text{Collection Time}}$$

or

$$\gamma H/L = 5.558 \times \frac{\text{Titration Time}}{\text{Collection Time}}$$

Analysis of H Vapor from Chamber

Time	Titration Time (min.) (Blank Subtracted)	Collection Time (Min.)	γ H/L	H Added (ml.)
1308	0.00	0.00	0.0	1.2
1314	0.12	4.19	15.9	–
1319	0.20	4.27	26.5	–
1323	0.19	4.26	24.8	–
1328	0.17	4.24	22.3	–
1333	0.15	4.22	19.8	0.5
1334	Men entered the chamber			
1337	0.15	4.22	19.8	0.4
1342	0.16	4.23	21.0	0.4
1347	0.15	4.23	19.7	0.4
1351	0.15	4.22	19.8	0.4
1356	0.15	4.22	19.8	0.4
1401	0.14	4.21	18.5	0.5
1406	0.15	4.22	19.8	0.5
1410	0.17	4.24	22.3	0.5
1415	0.17	4.24	22.3	0.4
1420	0.17	4.24	22.3	0.4
1425	0.15	4.22	19.8	0.3
1433	0.16	4.23	21.0	0.4
1434	Men left the chamber			–

Summary

Concentration H Vapor (γH/L)

Average = 20.4 Maximum = 22.3 Minimum = 18.5
Average Deviation from mean = ± 1.0

Temperature (°F)

Average = 89.6 Maximum = 90.7 Minimum = 88.5

JAN 2 1944

TABLE XI (Cont'd)

Summary

Relative Humidity

Average = 67% Maximum = 71% Minimum = 63%

CT

Actual CT = (60 x 20.4) = 1224

II. INITIAL TESTS OF NAVY ISSUE PROTECTIVE CLOTHING AGAINST H VAPOR

SUBJECTS

75. There has never been any difficulty in getting volunteers for the experiments despite the fact that only two inducements were offered; i.e., leave and liberty--change of scenery. However, these facts definitely support the assumption that leave and new surroundings are still uppermost on the average sailor's priority list. Financial remunerations, which seem to play an important part in the rewards offered to volunteers in other countries, i.e., England, Canada, Australia, etc., have never been considered by us nor asked for by the men.

76. It has been impressed on the men that they are not "guinea pigs". They are told that they are expected to use their heads as well as their bodies; and if they do not understand anything to ask questions, these questions being answered in a simple and non-technical language.

77. During their stay at this activity, which varies from one to four weeks, the men pick up an amazing amount of gas warfare fundamentals and, if this is supplemented by a moderate amount of instruction, they leave with a basic amount of knowledge of defensive gas warfare which should be sufficient for the duties required of an enlisted man in the Navy Defensive Gas Warfare Program. The fact that has been most obvious throughout these experiments is that when the men first begin the work they should not be told too much. If they are, it sets up a fear reaction that remains for varying lengths of time and definitely affects their "virgin" runs in the chamber, and, occasionally, requires a removal from the chamber before the run is completed. However, after the first two runs in the chamber, the men become veterans and can be told almost anything without affecting their morale.

78. The men take any resulting casualty extremely well. Even the hospital cases, who, on a few occasions, were incapacitated for a month or so, were not upset and even volunteered for further trials.

79. Occasionally there have been individuals or groups who did not cooperate fully. A short explanatory talk, and, if necessary, a slight verbal "dressing down" has always proven successful. There has not been a single instance in which a man has refused to enter the gas chamber. Our opinion is that the men who have come through this program are much better equipped both mentally and physically to withstand gas warfare if and when it comes.

Physical Examination and Requirements

80. Emphasis must be placed on physical fitness. If not, the experiments are doomed to failure due to inability of the man to remain in the suits and masks and perform effectively when exposed to the high temperature and humidity of the chamber. The so-called false positive readings, due to physical unfitness, such as conjunctivitis, laryngitis, nausea, shock, etc., can easily be mistaken as gas manifestations. Another common symptom, headache, may be attributed to the tight mask straps, etc., when it is actually due to a systemic condition not caused by the chamber. In this connection, it may also be said that it is impossible to give the men liberty during a regular series of experiments and expect them to be in good physical condition the next morning; there always are a few that imbibe too freely and stay ashore too late to be in good condition for the experiments the next day. Because of the above conditions, a thorough physical examination is performed by the Medical Officer, particular attention being paid to the parts of the body most liable to be affected by the gas, i.e., the skin, eyes, genitalia, throat, etc. Many abnormalities are noted and also brought to the man's attention before he enters the chamber. This prevents false interpretations by both the examiner and the men.

81. As a supplement to the actual physical examination complete blood counts, urinalysis, and temperatures are taken; the work being done by qualified laboratory technicians. Blood counts are repeated after a cumulative CT of 4800. The history of each man is briefly checked by the Medical Officer, emphasis being placed on asthma, allergy, hay fever, skin diseases, etc. At this time, a quick psychological impression is also obtained.

82. Upper respiratory infections are the most common disabling factors, and if objective symptoms are present, the man is not sent into the gas chamber. Immediate treatment is instituted and it is usually possible to use the man in a later experiment. This procedure also applied to any other minor physical disability.

83. No man is sent into the chamber without the Medical Officer's approval. Occasionally, at this point, malingerers and psychoneurotics are discovered. These cases have all been handled so far by minimizing their symptoms and then sending them into the chamber.

GENERAL PROCEDURE FOR CHAMBER TESTS

84. Each man exposed in the chamber was equipped with the following:

a) Navy diaphragm masks, Mark III.
b) Impregnated Arnzen protective suits.
c) Standard Navy underwear (unimpregnated).
d) Impregnated cotton socks and impregnated elbow length wool gloves.
e) Overshoes (Arctics).
f) Protective ointment for face and neck.
g) Impregnated undershorts for exposure to CT's above 1000. (Heavy cotton rib-knit underwear cut off at knee and rolled to give gas-tight fit.)

85. The impregnated Arnzen protective suits used in these tests were of three types.

a) Water suspension - Impregnated in a Navy Portable Plant with a water suspension at room temperature using the following formula: 100 S-145/75 CP/25 ZnO/3.75 PVA/0.75 Daxad 11/0.15 Duponol ME/9 Pigment, with enough water added to give a bath containing approximately 10% S-145.

b) Solvent - Impregnated in a Navy M-1 Plant with a solution of S-145 in tetrachloroethane at 55°C.

c) Solvent + ZnO - Impregnated in a Navy M-1 Plant with a solution of S-145 in tetrachloroethane containing 15% ZnO based on the weight of S-145 at 35°C.

86. The physically fit men chosen for a given test were instructed in the use of the gas mask and then checked with masks on in an atmosphere containing a high concentration of a lachrymator (CN). This was done to make sure the masks fitted properly without leakage. The men wore dungarees in this test to avoid subsequent contamination of the chamber atmosphere.

87. The men then dressed in protective clothing under close supervision to insure gas-tight seals at waist, face, ankles and wrists. Unimpregnated underwear was put on first, then impregnated shorts, followed by suit, socks, arctics, ointment, gloves and mask. Protective ointment was applied to the neck and face extending just inside the edge of the mask facepiece. A final inspection was made of masks and clothing just before the men entered the chamber.

88. Before each chamber test, qualified persons were required to sign a log attesting to the satisfactory condition of the following: (a) canisters, (b) active chlorine content of clothing, (c) concentration of agent in the chamber, (d) physical condition of the men, (e) proper adjustment of protective clothing and masks.

89. The men entered the chamber through the antechamber in groups of five. The chamber was operated under conditions considered average for the tropics, namely, 90°F, 65% Relative Humidity (R.H.).

90. Continuous visual and audio communication was maintained between the officer in charge and the men in the chamber. Every five minutes each man was required to move to a position on the opposite side of the chamber, otherwise they were permitted to move about at will. The time of each exposure was one hour, after which the men left the chamber and remained in the open five minutes to aerate their clothing and then removed their masks and gloves. The clothing was worn an additional four hours, outdoors in the shade on warm days and in a room at 75-80°F on cold days. During this time the men were not exercised but were allowed to move about freely.

91. Clothing was removed and the men were examined immediately and at subsequent twenty-four hour intervals, the areas most vulnerable to H vapor being closely checked. The face and neck were examined for evidences of ointment irritation.

EXPERIMENTAL RESULTS

Test No. 1 - Irritancy of Impregnated Arnzen Suits

92. In order to determine the irritancy of the Protective Clothing under severe conditions, ten men with full equipment were subjected to a temperature of 96°F and 81% R.H. in the chamber for one hour. Five of the men wore Arnzen suits impregnated with S-145 by the water suspension process, and the other five men wore Arnzen suits impregnated by the solvent process (without ZnO). S-461 Protective Ointment (15% Cl^+) was applied to the neck and face at the edges of the mask before the test. The results are summarized in Table XII. The outside temperature was 90°F and the R.H. was 37%.

TABLE XII

IRRITANCY OF PROTECTIVE SUITS

Impregnation	Physical Examination 0 hrs.	Physical Examination 24 hrs.
Solvent	0 neg. 5 pos. 2 cases of mild conjunctivitis; 3 cases of erythema of face; 4 cases of erythema of body or limbs.	4 neg. 1 pos. 1 case of mild erythema of back.
Water Suspension	0 neg. 5 pos. 1 case of mild conjunctivitis; 3 cases of erythema of face or neck; 3 cases of erythema of body or limbs	3 neg. 2 pos. 1 case of desquamation of face; 1 case of mild erythema of back.

93. A considerable number of the immediate positive reactions obtained in this test were due to the ointment. The others were due to the clothing and/or high temperatures. With the exception of two cases they were only of a transient character. There was no significant difference between the two types of suits.

Test No. 2 - Exposures to H Vapor with Increasing CT

94. To determine the effects of different CT values at which protected men might be exposed, and the optimum CT for chamber exposures, a screening series was run on the three different types of S-145 impregnated clothing, namely, water suspension, solvent, and solvent + ZnO. This series was begun with a low CT which was increased in subsequent exposures up to 2500. Five men in each group with complete protective clothing including S-461 Protective Ointment were exposed to H vapor in the standard manner for one hour. The water suspension and solvent groups were run together, the solvent + ZnO separately. The results are summarized in Tables XIII to XV for the 48-hour reading unless specified otherwise. Samples were taken for active chlorine analysis from widely separated areas of an average of two suits out of each group of five after each exposure. New suits were used for each exposure and new men as indicated. The results do not include ointment irritation.

TABLE XIII

EXPOSURES TO H VAPOR WITH INCREASING CT - WATER SUSPENSION IMPREGNATION

CT	γH/L	Conditions in Chamber T	Conditions in Chamber RH	Conditions Outside T	Conditions Outside RH	Cl^+ Analysis mg.Cl^+/cm.^{2} before	Cl^+ Analysis mg.Cl^+/cm.^{2} after	Results neg.	Results pos.	(48 hrs.)	New Men Used
190	3.2	90	73	90	40	.63	.57	5	0		5
300	5.0	89	65	91	44	.63	.64	5	0		3
490	8.1	90	64	87	48	.63	.55	4	1		0
640	10.7	90	64	77	59	.63	.53	5	0	(24hrs.)	5
850	14.1	90	63	89	41	.66	.62	5	0		5
990	16.5	90	66	90	50	.66	.62	3	2		0
1260	21.0	91	66	80	68	.63	.58	3	2		5
1510	25.2	91	60	76	53	.67	.73	4	1	(24hrs.)	5
1730	28.8	90	70	83	55	.73	.73	2	3		1
2030	33.8	90	65	73	52	.55	.51	2	2	(24hrs.)	4
2220	37.0	90	65	81	57	.61	.60	2	2		4
2600	43.4	90	65	87	40	.55	.53	1	3	(24hrs.)	4

TABLE XIV

EXPOSURE TO H VAPOR WITH INCREASING CT - SOLVENT IMPREGNATION

CT	γH/L	Conditions in Chamber T	Conditions in Chamber RH	Conditions Outside T	Conditions Outside RH	Cl^+ Analysis mg.Cl^+/cm.^{2} before	Cl^+ Analysis mg.Cl^+/cm.^{2} after	Results neg.	Results pos.	(48 hrs.)	New Men Used
190	3.2	90	73	90	40	.42	.41	5	0		5
300	5.0	89	65	91	44	.42	.37	5	0		5
490	8.1	90	64	87	48	.42	.38	2	3		1
640	10.7	90	64	77	59	.42	.38	5	0	(24hrs.)	5
850	14.1	90	63	89	41	.42	.38	5	0		5
990	16.5	90	66	90	50	.42	.37	2	3		0
1260	21.0	91	66	80	68	.42	.39	5	0		5
1510	25.2	91	60	76	53	.42	.42	5	0	(24hrs.)	5
1730	28.8	90	70	83	55	.42	.39	3	2		0
2030	33.8	90	65	73	52	.37	.32	3	1	(24hrs.)	4
2220	37.0	90	65	81	57	.35	.30	2	2		4
2600	43.4	90	65	87	40	.35	.32	3	1	(24hrs.)	4

TABLE XV

EXPOSURES TO H VAPOR WITH INCREASING CT
SOLVENT + ZnO IMPREGNATION

CT	γH/L	Conditions in Chamber T	Conditions in Chamber RH	Conditions Outside T	Conditions Outside RH	Cl^+ Analysis mg. $Cl^+/cm.^2$ before	Cl^+ Analysis mg. $Cl^+/cm.^2$ after	Results (48 hrs) neg.	Results (48 hrs) pos.	New Men Used
490	8.2	90	65	78	59	.44	.40	5	0 (24hrs)	5
1120	18.7	90	65	73	63	.44	.39	4	1	5
1540	25.7	90	65	65	37	.44	.38	1	4	0 (2ndExp.)
2000	33.4	90	65	70	43	.44	.39	0	5 (24hrs)	0 "
2480	41.4	90	65	78	52	.44	.38	3	2	0 (3rdExp.)

95. Positive reactions were usually obtained when the men in the test had been exposed twice or more, indicating that there is a slight leakage through the suits which is cumulative in its action so that it gradually builds up from a sub-clinical to a clinical burn. For the most part these positive reactions consisted of a questionable to a mild erythema of the dorsal thorax which was accentuated by the lack of erythema under the crossed shoulder straps and/or of the shoulders and upper arms. Since impregnated undershorts were worn at CT's above 1000, no evidences of reaction were observed on the genitals or inguenal region.

96. On the average, there was a definite loss of active chlorine in a suit during each exposure. However, this loss is too slight (being within experimental error) to show a definite relationship to the concentration of H vapor.

97. It can be concluded that all three types of suits, when new, give adequate protection for at least one exposure at any CT covered by this series of tests.

Test No. 3 - Repeated Exposures to H Vapor at CT 1200

98. A series of tests (still in progress) is being carried out in an effort to determine how many exposures to H vapor each of the three different types of S-145 impregnated clothing, namely, water suspension, solvent and solvent + ZnO will stand before "breaking" (that point at which a previously unexposed subject will show a positive reaction after his first exposure in the suit at CT 1200). Five men in each group, for each type of impregnated clothing, including impregnated undershorts, and at first S-461 and then S-330 Protective Ointment, were exposed to H vapor in the standard manner for one hour. The chamber conditions were 90 ± 1°F and 65 ± 3% R.H. The water suspension and solvent groups were run together, the solvent + ZnO separately. The results are summarized in Tables XVI to XVIII for the 24-hour reading unless specified otherwise. The same suits, without laundering, were used throughout the series and the total number of exposures for each man are indicated. The positive reactions for each test are marked with an asterisk. From three to five tests were run each week. The results do not include ointment irritation.

TABLE XVI

REPEATED EXPOSURES TO H VAPOR AT CT 1200 - WATER SUSPENSION IMPREGNATION

Expo-sure	CT	χH/L	Conditions Outside T	RH	Cl^+ Analyses mg.Cl^+/cm.^{2} before	after	Results (24 hrs.) neg.	pos.	No. of previous exposures for man in suit No. 6	7	8	9	10
1	1220	20.3	65	91	.77	.58	5	0 (48 hrs.)	0	0	0	0	0
2	1150	19.2	78	59	.58	.59	4	1 (48 hrs.)	1	1	0	1	1*
3	1150	19.2	67	74	.59	.61	4	1	2	2	1	0	2*
4	1230	20.5	69	72	.61	.57	2	3	3*	3	2	1*	2*
5	1270	21.2	79	50	.57	.60	2	3 (48 hrs.)	4*	2	1	2*	3*
6	1280	21.4	59	70	.60	.54	4	1 (48 hrs.)	5*	3	2	3	3
7	1200	20.0	76	80	.54	.62	3	2 (72 hrs.)	6	4*	3	4*	4
8	1190	19.8	59	33	.62	.54	1	4 (48 hrs.)	4*	4	4*	5*	3*
9	1220	20.4	56	40	.54	.57	2	3	0*	0	0	0*	0*
10	1190	19.8	52	60	.57	.52	2	3	0	1	1*	1*	1*
11	1220	20.4	66	37	.52	-	1	4	1	2*	2*	2*	2*
12	1220	20.3	67	62	-	.57	0	5	2*	3*	3*	3*	3*
13	1210	20.1	47	98	.57	.51	4	1	0	0	0	0	0*
14	1190	19.8	50	76	.51	.58	0	5	1*	1*	1*	1*	1*
15	1210	20.1	51	95	.58	.58	0	5 (48 hrs.)	2*	2*	0*	2*	2*
16	1220	20.3	Autumn		.58	.60	3	2 (48 hrs.)	0	0*	0	0*	0
17	1190	19.8	Weather		.60	.40	0	5	1*	1*	1*	1*	1*
18	1220	20.4	(Nov.)		.40	.48	0	1 (48 hrs.)	-	-	2*	-	-
18A	1200	20.0	Men		-	-	2	2	0*	0	-	0	0*
19	1270	21.2	Inside		.48	-	0	1	-	-	0*	-	-
19A	1230	20.3			-	-	0	4 (48 hrs.)	1*	1*	-	1*	1*
20	1190	19.9			-	.41	0	1	-	-	1*	-	-
21	1220	20.3			.41	.41	0	1	-	-	2*	-	-

Total 22,980**

** Suit No. 8 had a total CT of 25,460

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TABLE XVII

REPEATED EXPOSURES TO H VAPOR AT CT 1200 - SOLVENT IMPREGNATION

Expo-sure	CT	γE/L	Conditions Outside		Cl^+ Analyses mg.Cl^+/cm.^{2}		Results (24 hrs.)		No. of previous exposures for man in suit No.				
			T	RH	before	after	neg.	pos.	1	2	3	4	5
1	1220	20.3	65	91	.34	.41	5	0 (48 hrs.)	0	0	0	0	0
2	1150	19.2	78	59	.41	.35	4	1 (48 hrs.)	1	1	1	1*	1
3	1150	19.2	67	74	.35	.32	4	1	2	2	2	2*	2
4	1230	20.5	69	72	.32	.36	0	5	3*	3*	3*	3*	3*
5	1270	21.2	79	50	.36	.30	2	3 (48 hrs.)	4	4*	4*	4*	4
6	1280	21.4	59	70	.30	.33	2	3 (48 hrs.)	2*	5	2*	5*	5
7	1200	20.0	76	80	.33	.31	2	3 (72 hrs.)	3*	6	2*	3*	2
8	1190	19.8	59	33	.31	.29	1	4 (48 hrs.)	7*	7*	5	4*	5*
9	1220	20.4	56	40	.29	.27	3	2	0*	0	0	0	0*
10	1190	19.8	52	60	.27	.31	3	2	1*	1	1*	1	1
11	1220	20.4	66	37	.31	-	3	2	2*	2*	2	2	2
12	1220	20.3	67	62	-	.31	3	2	3*	3	3*	3	3
13	1210	20.1	47	98	.31	.29	4	1	0	0*	0	0	0
14	1190	19.8	50	76	.29	.23	2	3	1	1*	1*	1*	1
15	1210	20.1	51	95	.23	.18	3	2 (48 hrs.)	2	2*	2	2	2*
16	1220	20.3	Autumn		.18	.15	5	0 (48 hrs.)	0	0	0	0	0
17	1190	19.8	Weather		.15	-	2	3	1*	1	1*	1	1*
18	1220	20.4	(Nov.)		-	.10	1	4 (48 hrs.)	2*	2*	2*	2	2*
19	1270	21.2	Men		.10	-	3	2	0	0	0*	0	0*
20	1190	19.9	Inside		-	.08	1	4	1*	1	1*	1*	1*
21	1220	20.3			.08	.08	0	5 (48 hrs.)	2*	2*	2*	2*	2*

Total 25,460

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TABLE XVIII

REPEATED EXPOSURES TO H VAPOR AT CT 1200 - SOLVENT + ZnO IMPREGNATION

Exposure	CT	%E/L	Conditions Outside T	Conditions Outside RH	Cl^+ Analyses mg.Cl^+/cm.^{2} before	Cl^+ Analyses mg.Cl^+/cm.^{2} after	Results (24 hrs.) neg.	Results (24 hrs.) pos.		No. of previous exposures for man in suit no. 11	12	13	14	15
1	1210	20.1	49	98	.44	.41	3	2		0*	0	0	0*	0
2	1190	19.8	52	73	.41	.35	1	4		1*	1*	1*	1*	1
3	1260	21.0	51	94	.35	.40	0	4	(8 days)	-	2*	2*	2*	2*
4	1240	20.6	Autumn		.40	.33	4	1	(48hrs.)	0	0	0*	0	0
5	1240	20.6	Weather		.33	.36	4	1		1	1	1*	1	1
6	1240	20.7	(Nov.)		.36	.40	2	3		2*	2*	2*	2	2
7	1220	20.4	Men		.40	.33	1	4	(48hrs.)	3	3*	3*	3*	3*
8	1200	20.0	Inside		.33	.27	3	2		0	0	0*	0	0*
9	1250	20.9			.27	.27	0	5	(48hrs.)	1*	1*	1*	1*	1*
TOTAL	11,050													

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99. The value CT 1200 was chosen for this series because this represents a CT approximately twice the average maximum practical CT obtained in field trials in Australia. This fact has been confirmed by the Canadians and British. Therefore, each exposure in the chamber should be more severe than a single exposure in the field.

100. Since the suits used in this series were exposed repeatedly, samples for active chlorine analysis were normally taken from the outer layer of the pockets and only occasionally from the arms or back or thighs. Usually samples were taken from two suits in each group. Due to unevenness of impregnation, especially around the pockets, the active chlorine analyses appear to be somewhat erratic, but the general trend downwards is quite obvious.

101. In the earlier part of this series (up to about exposure No. 12 for the water suspension and solvent groups, and No. 9 for the solvent + ZnO suits), for the most part the positive reactions consisted of a questionable to mild erythema of the dorsal thorax which was accentuated by the lack of erythema under the shoulder straps and/or of the shoulders and upper arms. These mild reactions resulted usually when the previous number of exposures was small. These reactions were so mild that in a number of cases they disappeared even though the subjects received further exposures. However, it is to be noted again that the effects of leakage are cumulative since most of the positive reactions occurred after several exposures on the same subject.

102. After about the 15th exposure, the reactions became more pronounced. In exposure No. 17, four of the men in the water suspension impregnated suits developed moderate erythemas indicating that these suits were approaching the "break-point". Accordingly, they were withdrawn from exposure No. 18 until new men were available. When these four suits were run on new men (No. 18A) only two mild reactions occurred. On the next exposure (No. 19A) on the same men, moderate to severe reactions occurred. In the solvent impregnated series, the positive reactions in exposures No. 19 and 20 (first and second exposures) were all mild. In exposure No. 21 (third exposure) all reactions were moderate to severe erythema.

103. Eight days after exposure No. 15, two men from the water suspension group and four men from the solvent group had reactions varying from a moderate erythema to vesication. This delayed action, which had not been observed previously, occurred mostly on the inner surfaces of the elbows and knees and above the ankles.

104. Eight days after exposure No. 3 in the solvent + ZnO group, all four men were well pigmented in the areas that had been burned and did not show any delayed reactions as in the other two groups.

105. No evidences of reaction were observed on the genitals or inguenal region after any of the tests since impregnated undershorts were worn in addition to the suits.

106. The leakage shown by these three types of suits increases with the number of exposures. This is shown in Table XIX where the values given are the averages for the total number of times one subject can be exposed without giving a positive reaction.

TABLE XIX

AVERAGE NUMBER OF EXPOSURES TOLERATED BY ONE SUBJECT BEFORE A POSITIVE REACTION RESULTS

After Suit	Subject Exposure		
Exposure No.	Water Suspension	Solvent	Solvent + ZnO
1	2.6	2.6	0.8 (?)
4			2.0
8			0.6
9	1.0	1.2	
13	0.8	1.2	
16	0.6	1.4	
18	0.4		
19		0.8	

107. It can be seen from the table that when the suits are new, two to three exposures are tolerated before the cumulative leakage is enough to produce a positive reaction, whereas after a suit has been exposed repeatedly, the leakage is great enough so that only one exposure may produce a positive reaction.

OINTMENT IRRITATION

108. As a safety precaution against leaks around the hoods, all men exposed in the chamber had Protective Ointment applied to the face under the edges of the mask, on and around the ears, and on the neck. Although the masks were worn for only one hour during the actual exposure, the ointment was not removed until the men undressed four hours later. In the early part of the tests S-461 Protective Ointment (10% Cl^+) was used, but when the men were subjected to more than one exposure, its use had to be discontinued due to excessive irritation on repeated applications. It was replaced by S-330 Protective Ointment (10% Cl^+) which has been used in all subsequent tests. The visible results of ointment irritation are summarized in Table XX. It is to be noted from the table that many cases of irritation had disappeared after 24 hours.

TABLE XX

OINTMENT IRRITATION

No. of Applications	S-461 Ointment: Total No. of men	S-461 Ointment: Irritation: On removing ointment	S-461 Ointment: Irritation: 24 hrs. later	S-330 Ointment: Total No. of men	S-330 Ointment: Irritation: On removing ointment	S-330 Ointment: Irritation: 24 hrs. later
1	88	36	20	87	10	1
2	26	14	12	72	14	1
3	1	1	1	47	4	0
4	-	-	-	22	6	2
5	-	-	-	7	1	1
6	-	-	-	2	0	0
7	-	-	-	1	1	0

109. The ointment irritation consisted for the most part of erythema at the edges of the face which was in contact with the mask. A few cases progressed to superficial desquamation similar to peeling after a mild sunburn. Two other common reactions were erythema of the neck and a laceration or maceration just under the ear lobes due to the rubbing in of the ointment by the lowest harness straps of the masks. In the case of S-461 Protective Ointment, the men usually complained of a strong burning sensation akin to that resulting from a severe sunburn or the use of a strong after-shave lotion even when there was no visible evidence of irritation. Only occasional complaints were heard from men using S-330 Protective Ointment. The irritation caused by the S-461 was much more severe than that caused by the S-330 Protective Ointment.

110. Perhaps the best demonstration of the difference in irritancy between S-461 and S-330 Protective Ointments was shown in a series of exposures in which five men having definite irritations from two to three applications of S-461 Protective Ointment and who could not have tolerated further applications, were able to continue the series of six to eight exposures using S-330 Protective Ointment even though the S-330 Protective Ointment was applied directly on the places that were irritated by S-461 Protective Ointment. Actually, after five total applications, one man had completely cleared up and two men had cleared up after six total applications. The other two men still had remains of the original irritation after the sixth application.

GAS MASKS BREAKS

111. The masks used in the earlier tests were the standard Navy Diaphragm masks, Mark III. These masks were tested for absorbed H periodically after every two to four exposures, using the "Spotted Dick" (S-328 Congo Red) paper at 35°C. In all cases negative tests were obtained. However, after about 12-15 exposures on each mask, marked physiological reactions consisting mainly of moderate cases of laryngitis, conjunctivitis and erythema with

pronounced pigmentation of the face began to appear showing that H vapor had penetrated at some point. The breaks were due to H absorbed in the rubber of the face-pieces and connecting rubber hose tubes. This was demonstrated by drawing a sample of air through the connecting hose tubes and a DB3-silica gel tube, followed by development of the DB3 tube. A strongly positive test was obtained.

112. These masks were decontaminated by aeration on a line outdoors. After one month of weathering, a faintly positive DB3 test was obtained on half the mask connecting hose tubes tested, and the other half giving a negative test. In this test air was drawn through the connecting hose and DB3 tube for one hour at the rate of 50 ml./min.

113. The area of exposed rubber in the hose connecting tubes is much larger than that of the face-piece, which in these tests is partially covered by the hood. Therefore, the larger part of the H vapor causing positive reactions is desorbed from the rubber of the hoses. In order to increase the effective life of the masks used in these tests, the connecting hoses of other masks were encased in S-145 impregnated cloth sleeves. Thus the only exposed part of the masks was the central part of the face-pieces not covered by the hood. Several of these masks have been through sixteen exposures with no signs of a break.

SCREENING TEST ON CT'S REQUIRED FOR BURNS ON BARE SKIN

114. A screening test was run in the chamber on the CT's required to give a man a burn on an unprotected area of the skin of the ventral surface of the forearm. Some of these tests were run along with another type of test so that quite a number of the men used had had previous exposures in the chamber and may have been slightly sensitized. It must therefore be emphasized that the results are useful only as a screen for further tests.

115. The procedure followed was to cut a hole about 3/4 to 1 inch in diameter through the glove and sleeve in the center of the ventral side of the forearm. A very short glass tube, 1/2 inch high and 3/4 inch inner diameter, having a 1/2 inch flat flange on the bottom, was placed through the hole, the flange being next to the skin to prevent trauma and leakage. The garments were then taped down tightly around the arm. However, in a few instances there was a slight slippage so that the same area of the skin did not receive the full exposure. With proper precautions, however, the method has been found satisfactory for this type of test. The men, otherwise completely protected, were exposed in the standard manner in the chamber. The results for the 24-hour reading and the number of previous exposures in the chamber for each man are given in Table XXI. The chamber was operated at 90 $\pm$ 1°F and 65 $\pm$ 3% R.H.

TABLE XXI

SCREENING TEST ON CT'S REQUIRED FOR BURNS ON BARE SKIN

No. of Men	CT	γH/L	Exp. Time (Min.)	Conditions Outside T	Conditions Outside RH	Results (24 hrs.)	Previous Exposures
5	114	1.9	60	67	84	2 neg.	0
						1E-?	4
						2E-	0,2
5	210	3.5	60	68	80	3 neg.	3
						1E-	3
						1E+	3
5	300	5.0	60	71	75	1E-?	1
						2E-	1
						2E	3,5
5	414	6.9	60	67	72	1E-?	4
						2E-	4
						1E	4
						1E+	4
5	594	9.9	60	63	69	4E-	5,5,6,6
						1E+	5
5	786	13.1	60	66	57	1E-	7
						1E	6
						3E+	6,6,7
4	804	13.4	60	50	93	2E	0
						2E+	0
4	996	16.6	60	53	92	2E	0
						2E+	0
1	1015	33.8	30	73	52	E+ (V in 48 hrs.)	0
7	2030	33.8	60	73	52	7V	0

Legend:
- E-? = trace
- E- = mild erythema
- E = moderate erythema
- E+ = papular erythema
- V = vesicle

116. The results obtained in this test show a very definite trend which is more obvious from the summarized table below (Table XXII), and from Plate 30. In Plate 30, the following arbitrary values have been assigned: E-? = 0.5, E- = 1, E = 2, E+ = 3, V = 4.

TABLE XXII

CT	Total No. of men	Reactions O	E-	E	E+	V
114	5	2	3			
210	5	3	1		1	
300	5		3	2		
414	5		3	1	1	
594	5		4		1	
786	5		1	1	3	
804	4			2	2	
996	4			2	2	
1015	1				1	
2030	7					7

SUMMARY AND CONCLUSIONS

1. A chamber for the exposure of human volunteers to the vapors of chemical warfare agents has been built and is in operation. The construction is such that the temperature, relative humidity and concentration of vapor of the chemical warfare agent can be controlled closely over wide ranges. The design, calibration and operation of the chamber are described in detail.

2. The subjects used in the tests are volunteer enlisted personnel who have just completed their basic training at the N.T.S., Bainbridge, Maryland. The men are given a thorough physical and laboratory examination before exposure in the chamber, and only those found physically fit are used for the tests.

3. A preliminary test was run to determine the irritancy of S-145 impregnated Arnzen protective clothing. The subjects developed transient erythema of the body and limbs, when exposed to 96°F and 81% R.H. for one hour, in both the water suspension and solvent type of impregnated suits. There was no significant difference between the two types, the erythema being due to the irritant qualities of the clothing and/or the high temperature during exposure.

4. A series of tests was run on the water suspension, solvent and solvent + ZnO S-145 impregnated Arnzen suits in which fully clothed men were exposed to H vapor at CT's ranging from 200 to 2500. At low CT's (up to 1200), positive reactions consisting of mild erythema of back, shoulders or arms occurred only if a man received more than one exposure. At a CT above 1200 some positive reactions occurred on a single exposure but none were severe even at a CT of 2500. It was concluded that new suits gave adequate protection for single exposures at a CT up to 2500 and there was no significant difference in the three types. The loss of active chlorine in any of these exposures was too small to measure its relationship to H vapor concentration.

5. A series of tests is in progress on the three types of suits in which fully clothed men have been given repeated exposures to H vapor at a CT of 1200 during one hour, followed by four hours wear of the clothing. The same suits, without laundering, are being used throughout the series, and the men are replaced after an average of three to four exposures. The water suspension suits have been exposed nineteen times at a total CT of 22,980, the solvent suits twenty-one times at a total CT of 25,660, and the solvent + ZnO suits nine times at a total CT of 11,050.

6. The tests have shown that there is a definite leakage of H vapor through all the suits. When a man is exposed a sufficient number of times with a short interval between exposures, a positive reaction results from the cumulative effect of this leakage. The leakage shown by these three types of suits increases with the number of exposures.

7. For the most part the burns varied in degree from the mildest type to moderate erythema with only occasional severe erythema and vesication. The majority of these burns reached their peak in 48-72 hours, but there have been a few cases of delayed reactions in which the peak occurred 5-8 days after the last exposure. Burns of the dorsal thorax, shoulders and arms predominated. The more sensitive areas of the body did not show the degree of erythema that was anticipated.

8. S-330 (10% Cl^+) Protective Ointment was far less irritating on single and repeated applications than S-461 (10% Cl^+).

9. After an average of 12-15 exposures in the chamber at a CT of 1200 each, the gas masks absorbed enough H to cause erythema and pigmentation of the face and moderate conjunctivitis and laryngitis. Other masks having the hose connecting tubes covered by impregnated cloth sleeves have not shown signs of a break after 16 exposures.

RECOMMENDATIONS

1. None. The chamber tests are being continued at high priority.

PLATE 1

OUTSIDE VIEW OF NRL GAS CHAMBER

A. Exhaust Duct

B. Door to Exhaust Blower Compartment

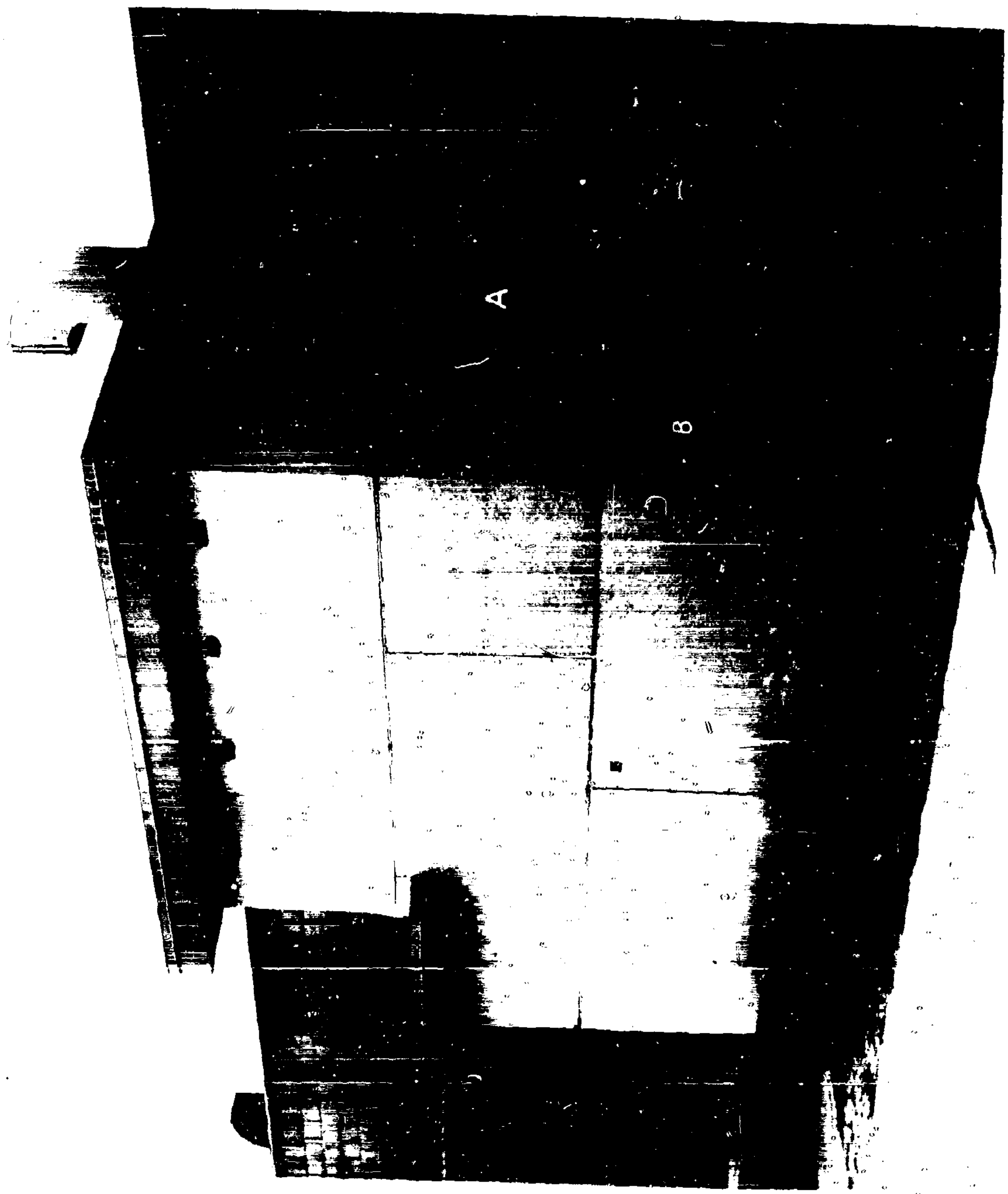

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PLATE I

PLATE 2

OUTSIDE VIEW OF NRL GAS CHAMBER

A. Porch

B. Ventilation Duct

C. Communication Master Station

D. Observation Window

E. Red Signal Light

F. Emergency Speaking Tube

G. Ventilator

H. Antechamber

J. Door to Antechamber

K. Skylight Windows

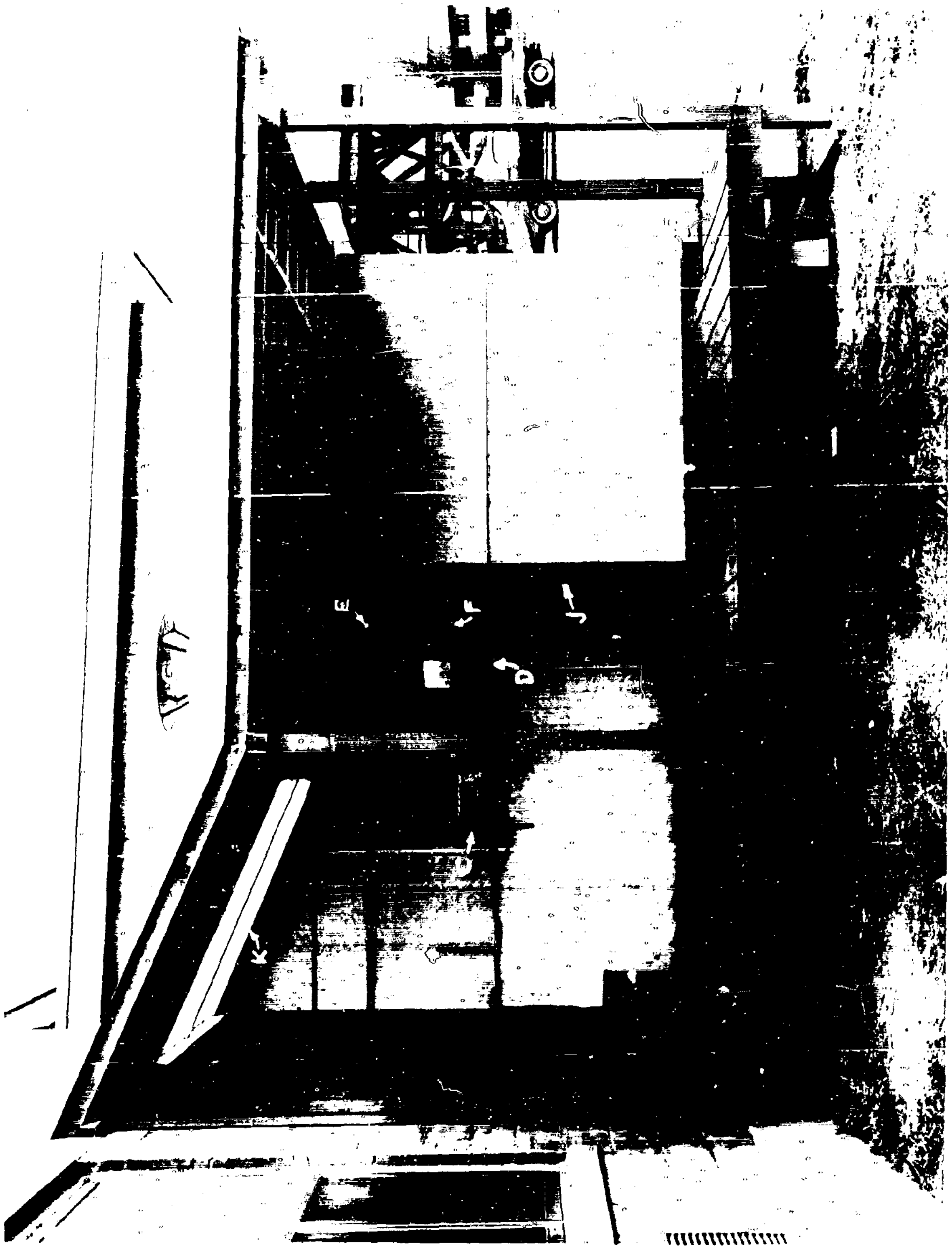

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PLATE 2

PLATE 3

INSIDE VIEW OF NRL GAS CHAMBER

A. Entrance from Antechamber

B. Emergency Speaking Tube

C. Observation Window

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PLATE 3

PLATE 4

INSIDE VIEW OF THE NRL GAS CHAMBER

A. Ice Cages

B. Drain Pan

C. Communication Station

D. Exhaust Blower Compartment

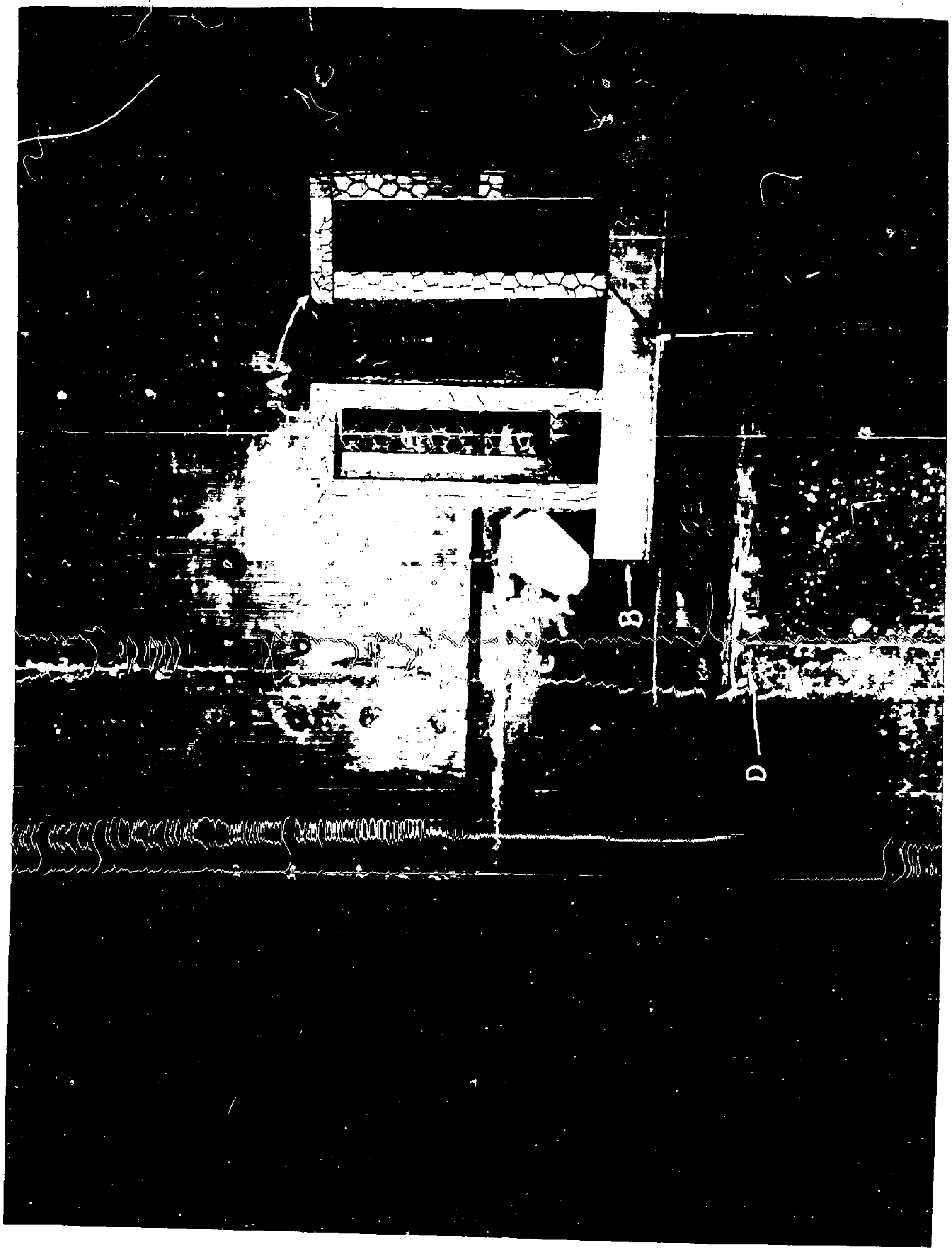

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PLATE 4

PLATE 5

INSIDE VIEW OF NRL GAS CHAMBER

A. Inlet from Flash Distillation Apparatus

B. Inlet from Bead Saturator

C. Sampling Tubes

D. "Dry Bulb" Thermocouple

E. "Wet Bulb" Thermocouple

F. Circulating Fans

G. Intermittent Heaters

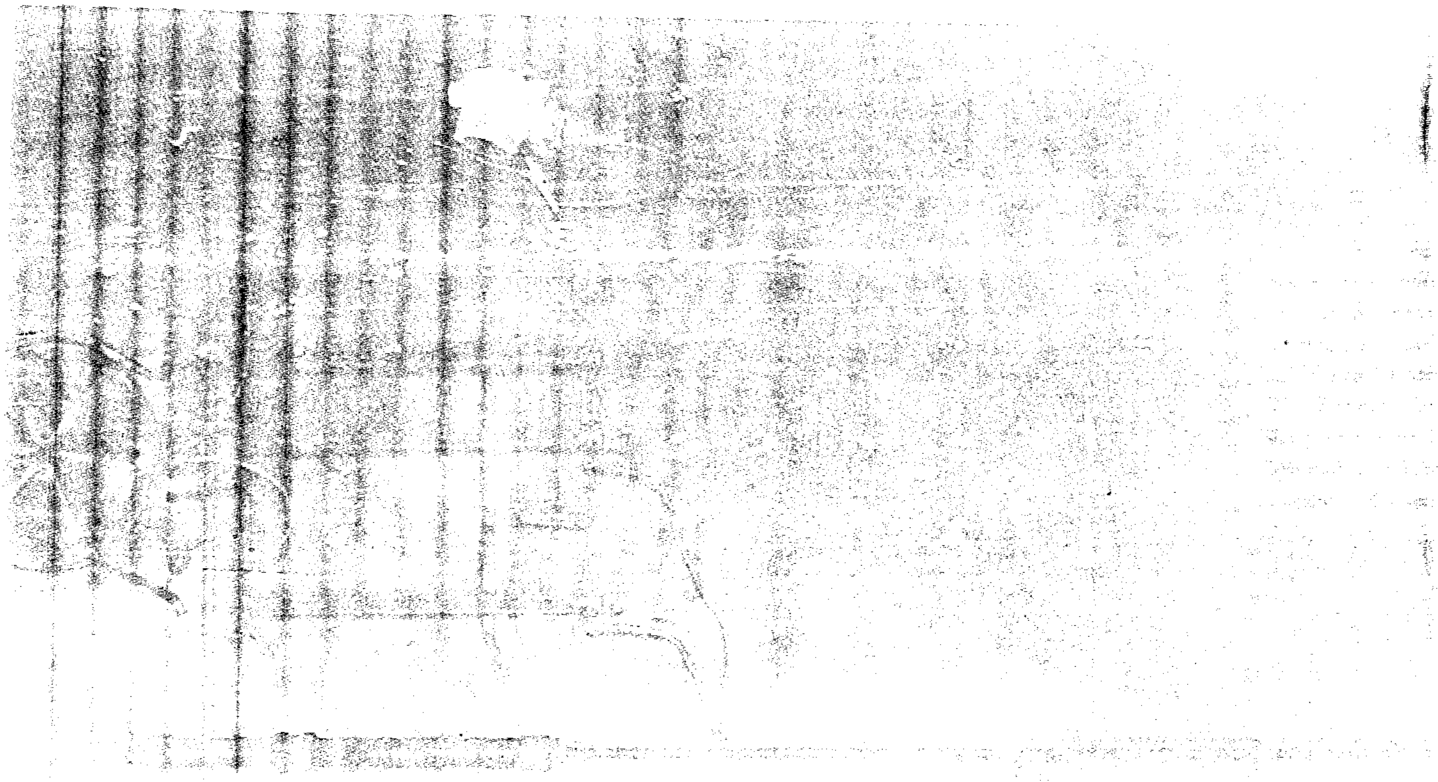
H. Continuous Heaters

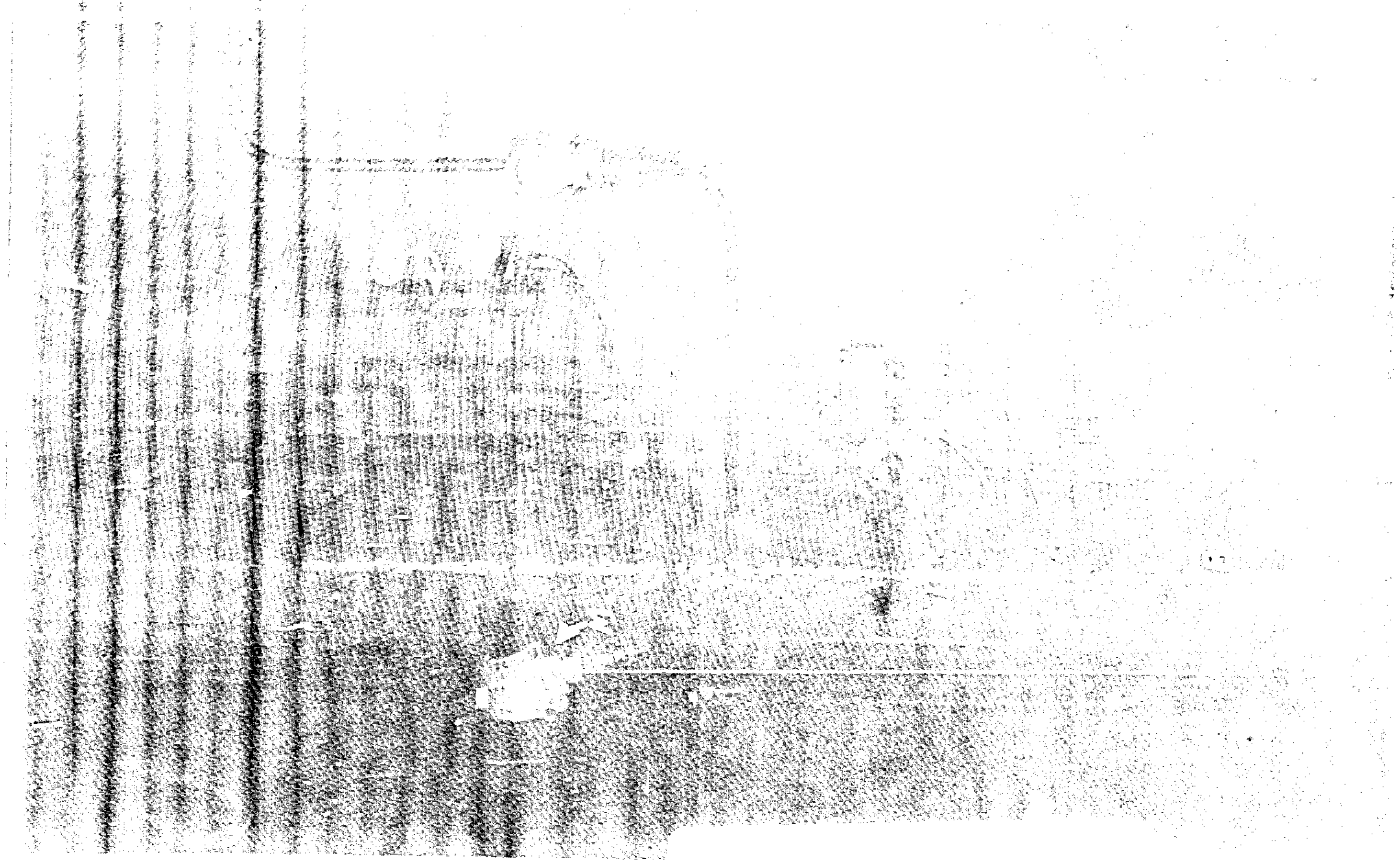
J. Steam Radiator

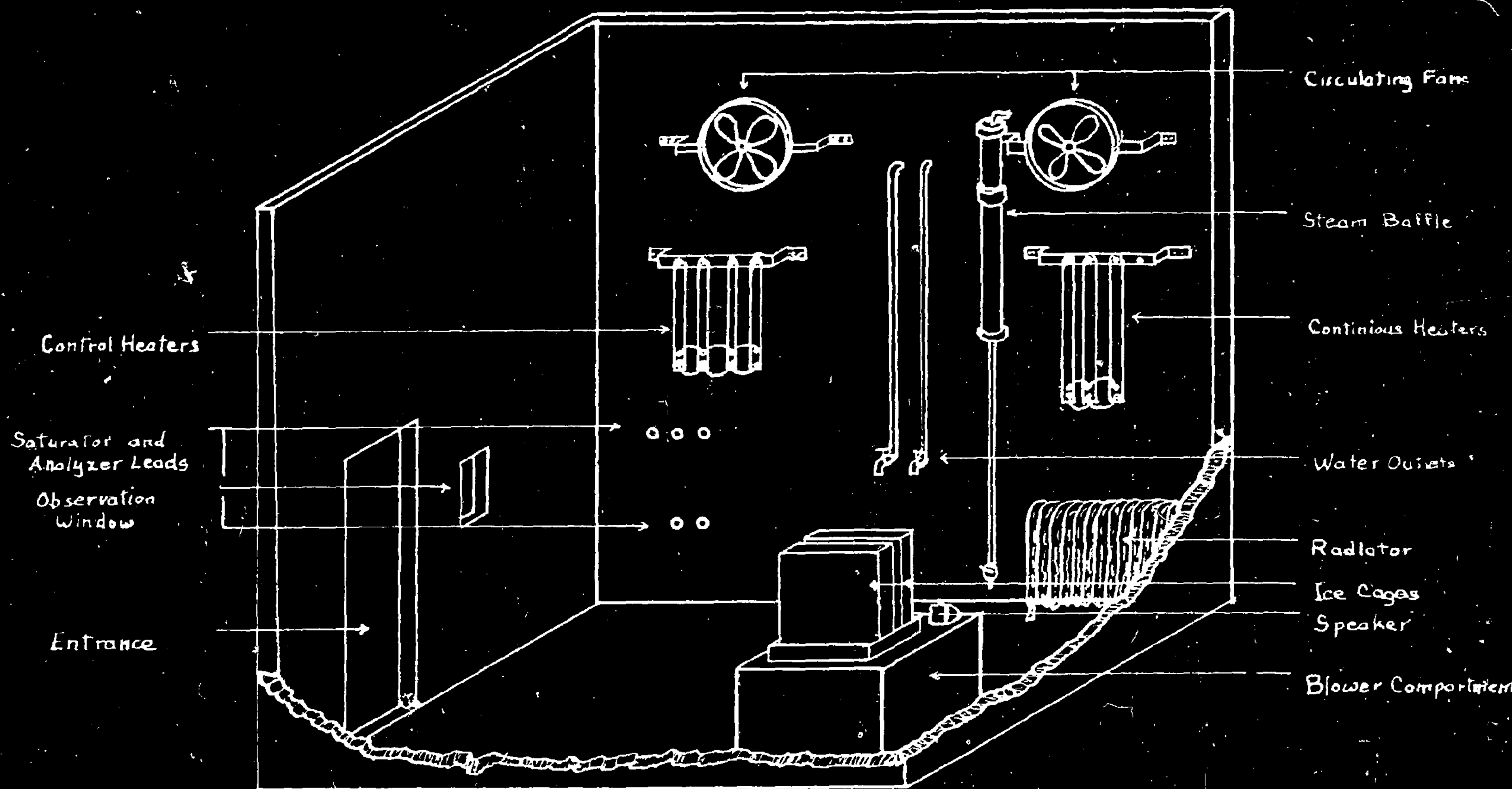
K. Steam Line (Humidification)

L. Hot and Cold Water Lines

M. Vapor Proof Electrical Outlets

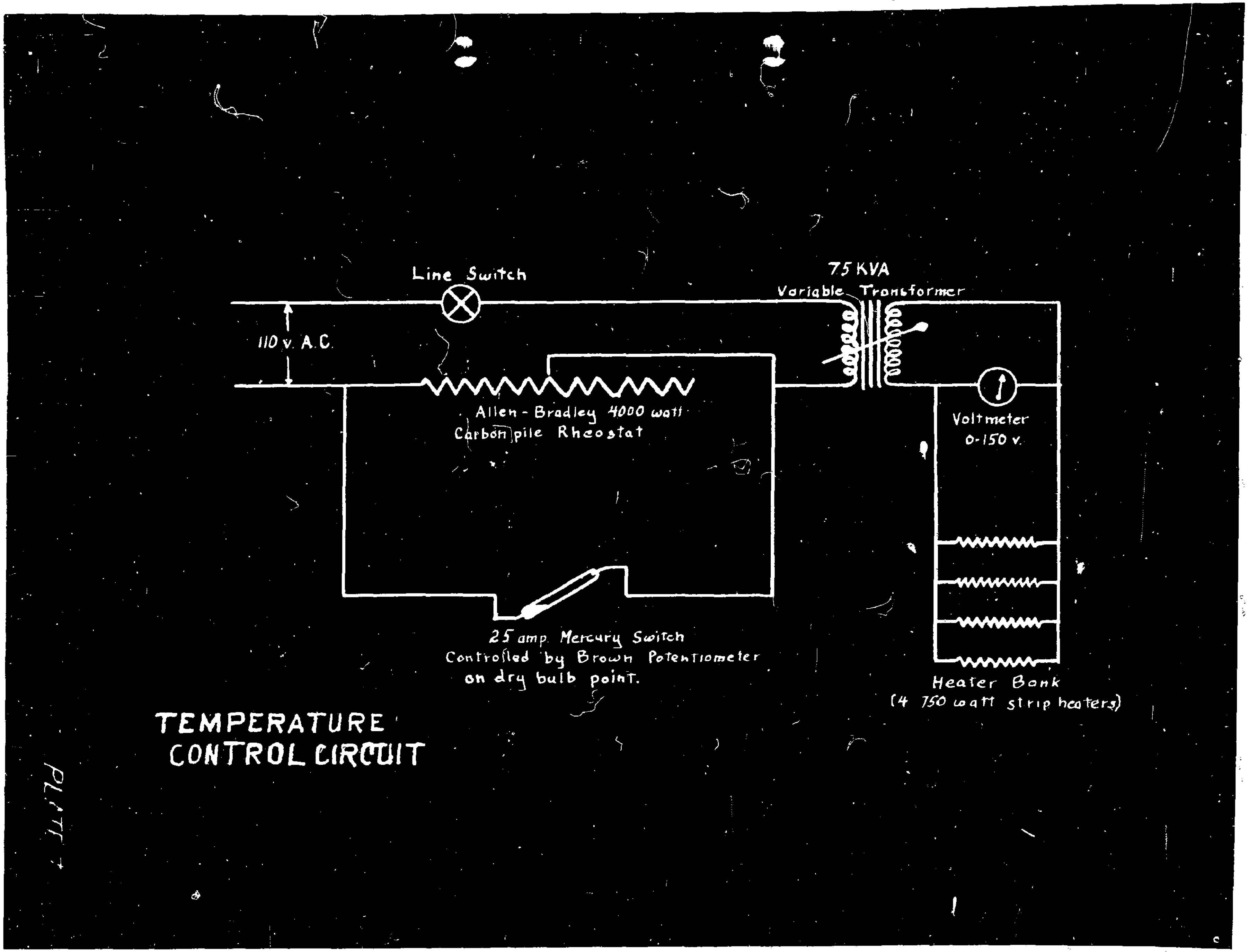


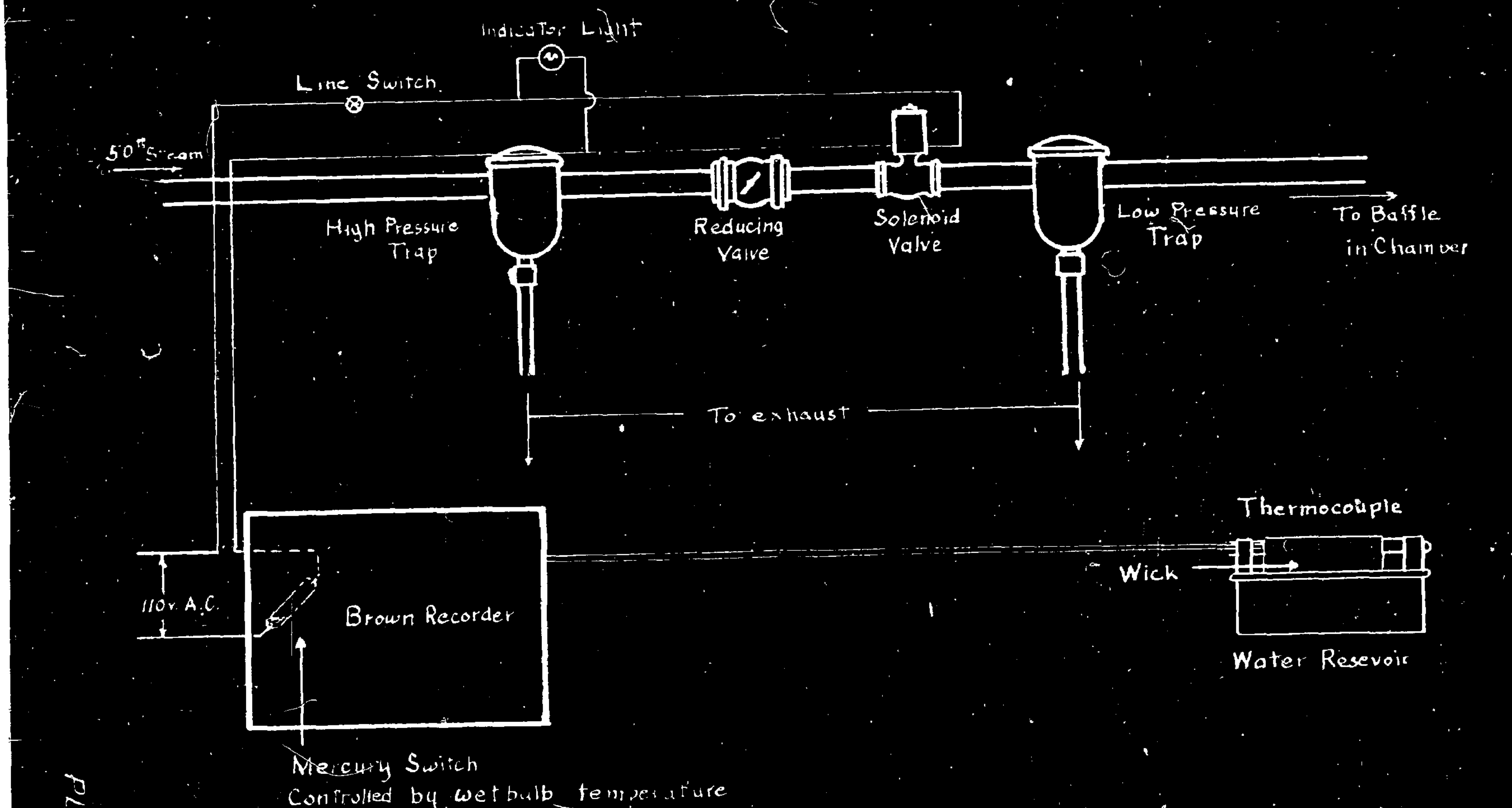




NRL GAS CHAMBER

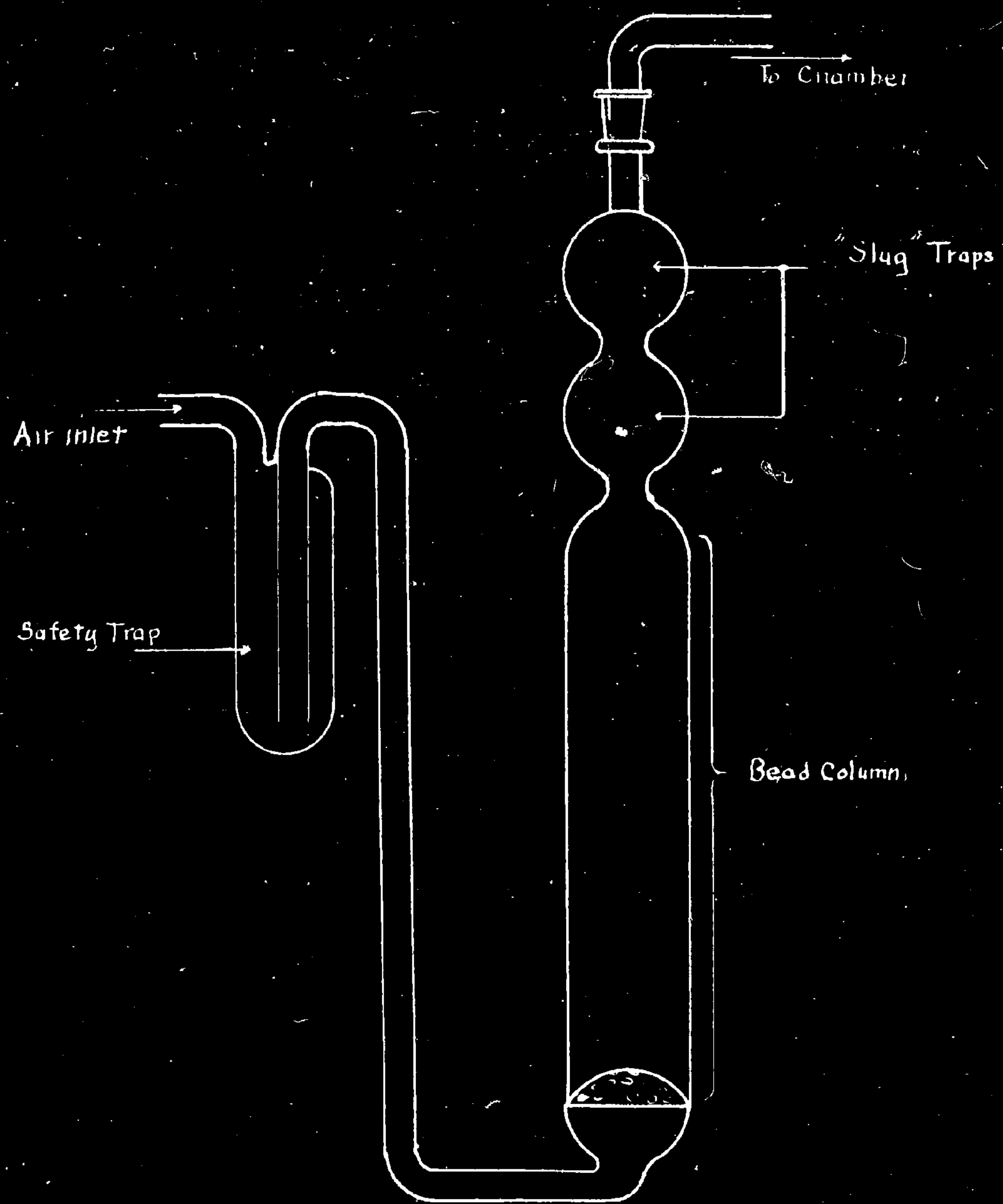
PLATE 6


Line Switch
110 v. A.C.
7.5 KVA
Variable Transformer
Voltmeter
0-150 v.
Allen-Bradley 4000 watt
Carbon pile Rheostat
25 amp. Mercury Switch
Controlled by Brown Potentiometer
on dry bulb point.
Heater Bank
(4 750 watt strip heaters)
TEMPERATURE
CONTROL CIRCUIT



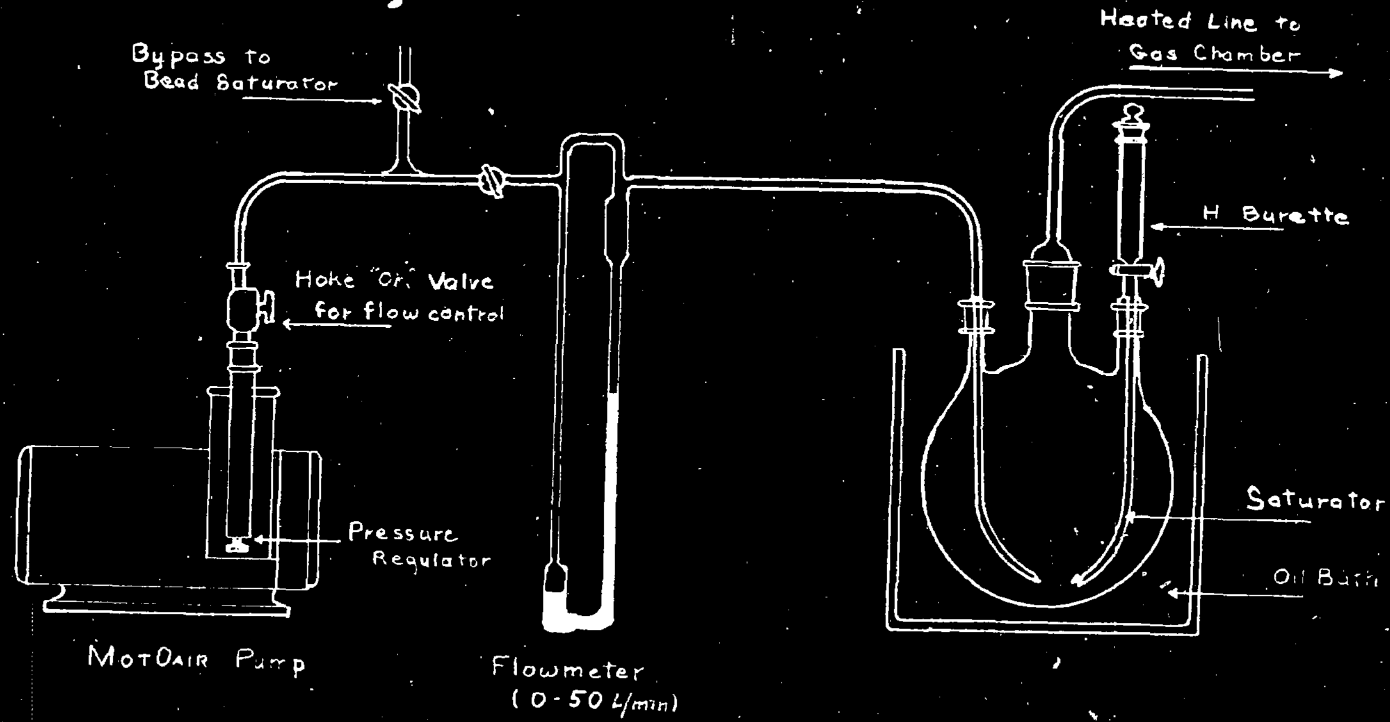
HUMIDITY CONTROL CIRCUIT

PLATE 8



BEAD SATURATOR

PLATE ,



FLASH DISTILLATION SYSTEM

PLATE 10

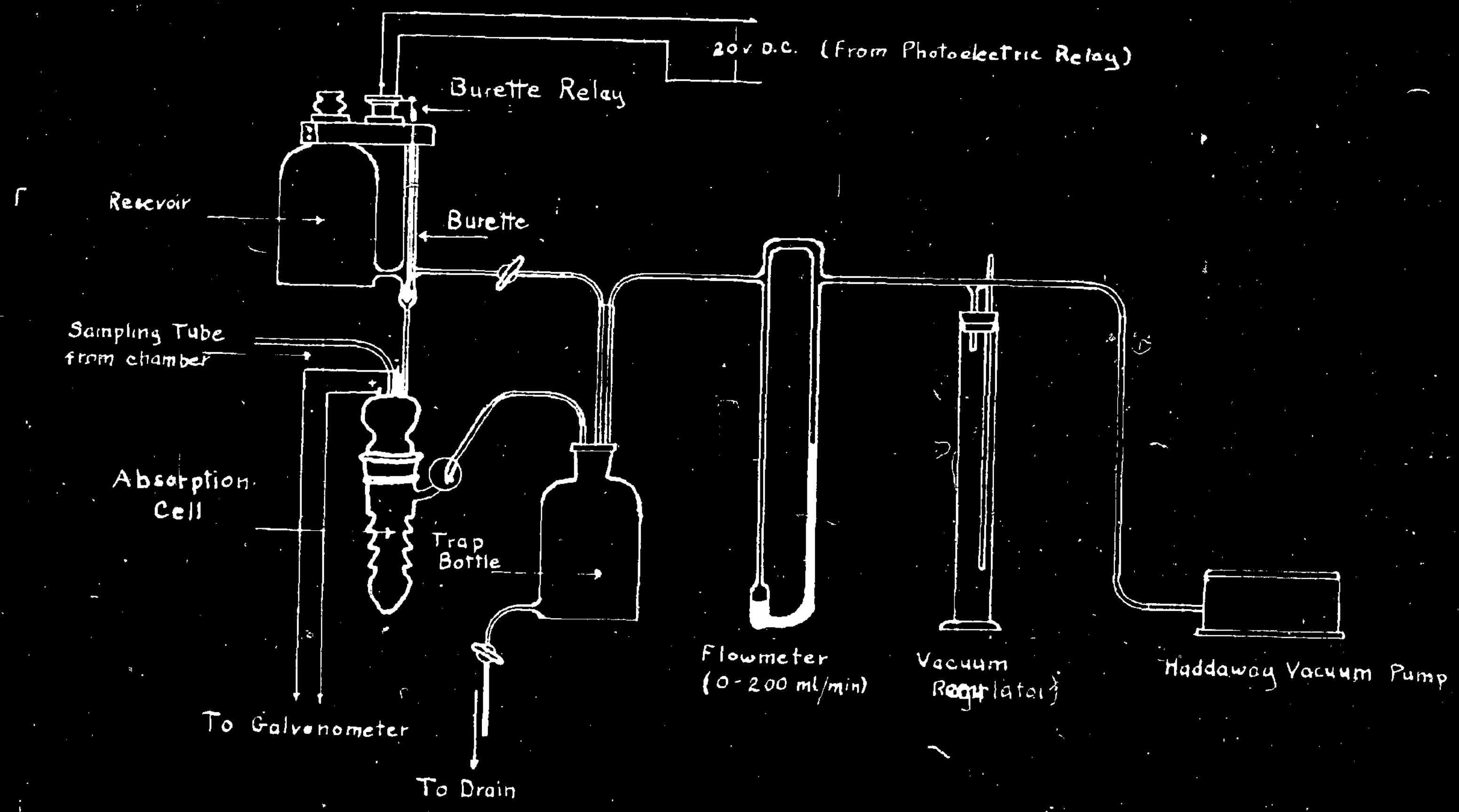


DIAGRAM OF NORTHRUP
WAR GAS ANALYZER

PLATE II

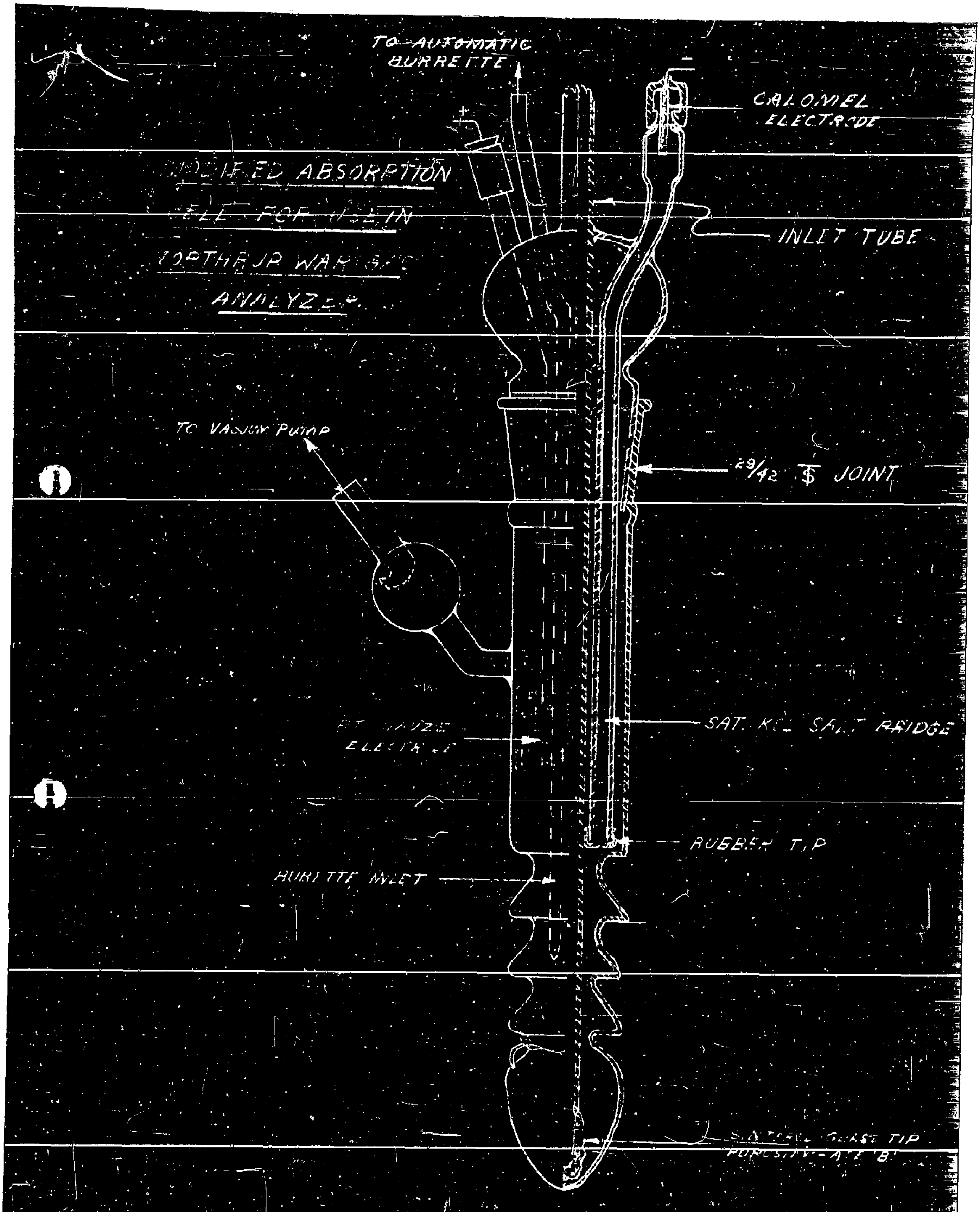
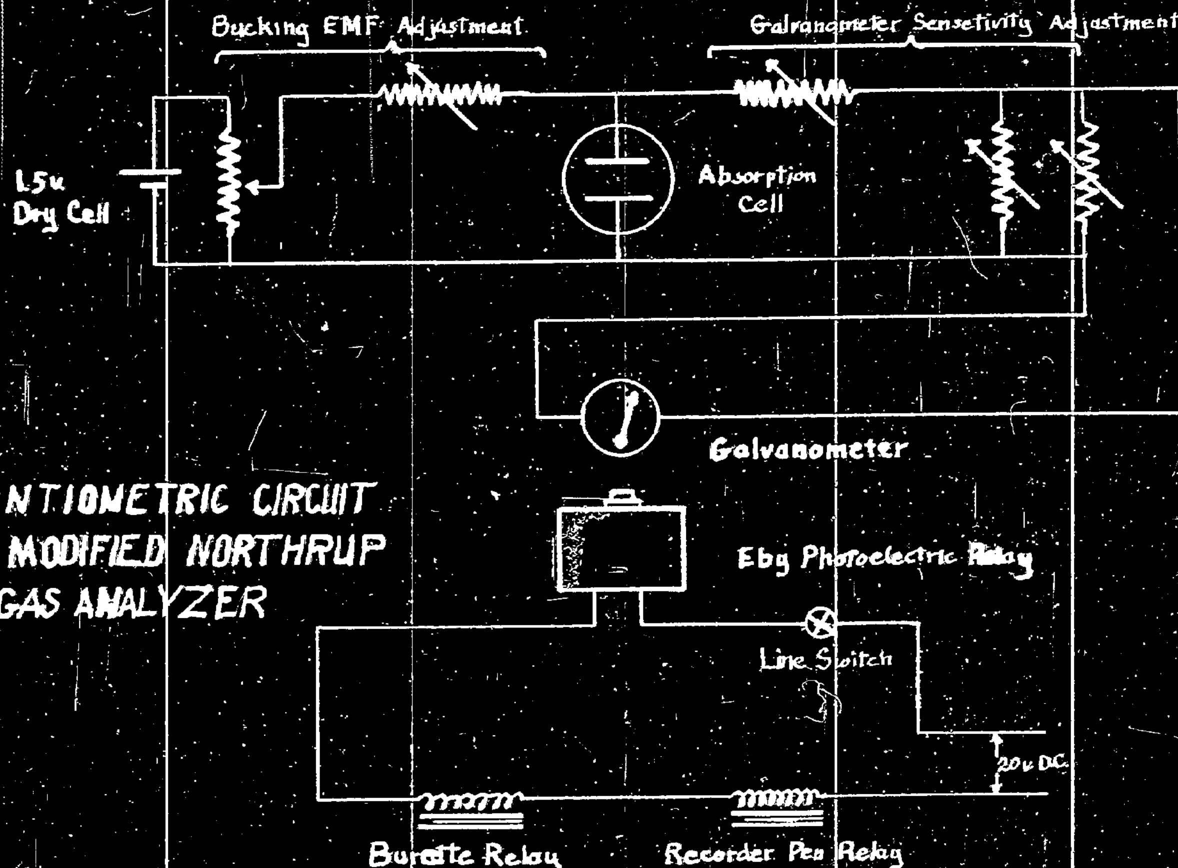
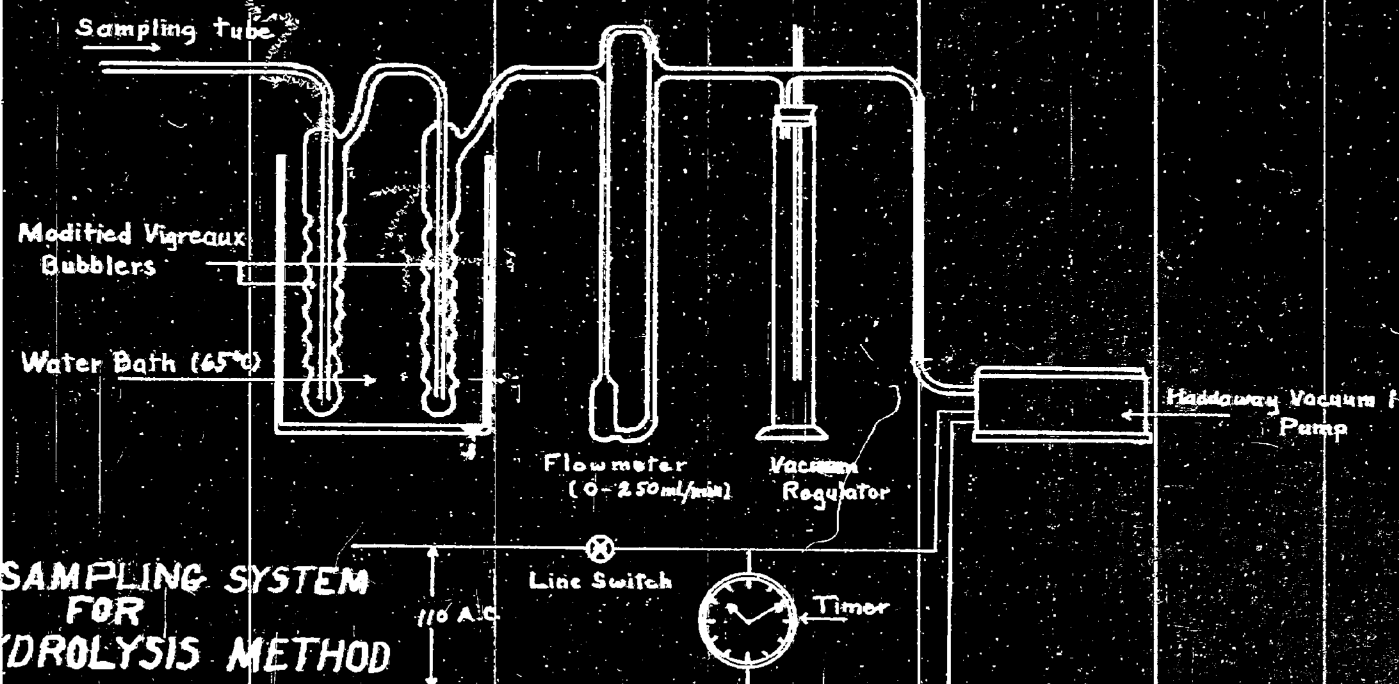

ABSORPTION
ANALYZER
TO AUTOMATIC
BURRETTE
CALOMEL
ELECTRODE
INLET TUBE
TO VACUUM PUMP
29/42 JOINT
RUBBER TIP

PLATE 12



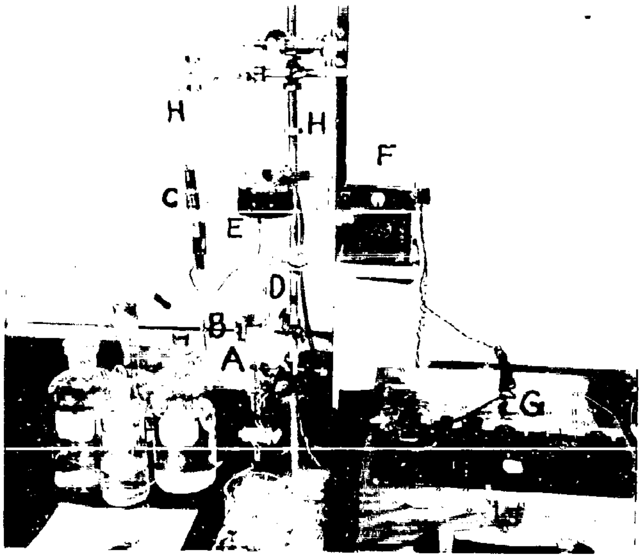
POTENTIOMETRIC CIRCUIT FOR MODIFIED NORTHRUP WAR GAS ANALYZER

PLATE 13



SAMPLING SYSTEM
FOR
HYDROLYSIS METHOD

PLATE 14



A. TITRATION CELL
B. K_2SO_4 BRIDGE
C. CALOMEL ELECTRODE
D. METALLIC ELECTRODE
E. STIRRING MOTOR
F. GALVANOMETER
G. POTENTIOMETER
H. BURETTE

PLATE 16

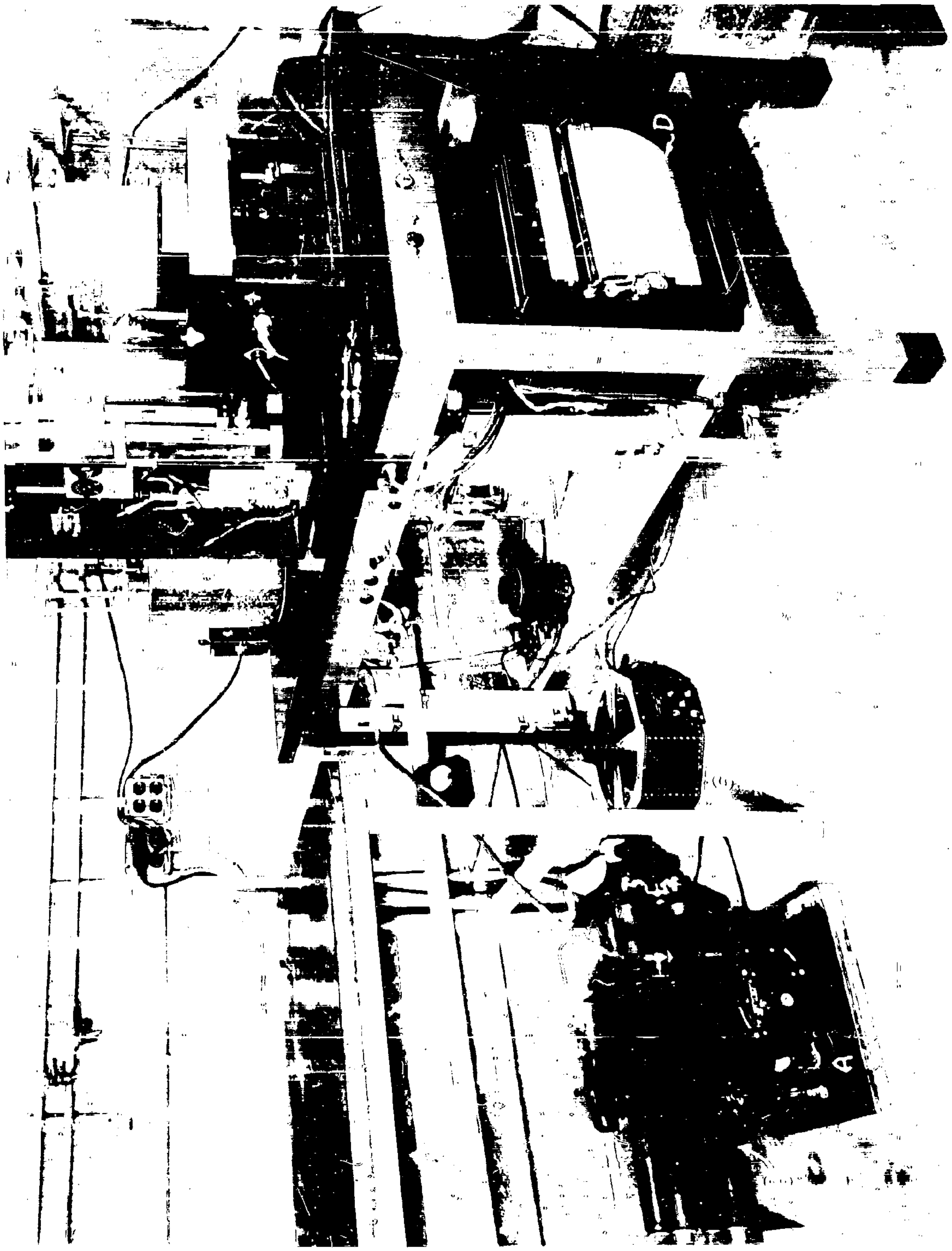
CONTROL APPARATUS FOR NRL GAS CHAMBER

A. "Motoair" Air Pump

B. Allen-Bradley Carbon Pile Rheostat

C. 7.5 K.V.A. Variac

D. Brown Two-Point Record Control Potentiometer



CONFIDENTIAL

PLATE 16

PLATE 17

APPARATUS FOR ESTABLISHING, ANALYZING
AND MAINTAINING GAS CONCENTRATIONS
IN NRL GAS CHAMBER

A. Flash Distillation Apparatus

B. Northrop Analyzer

C. Recorder for Northrup Analyzer

D. Metal Jacket Covering Bead Saturator

E. Flow Meter for Hydrolysis Sampler

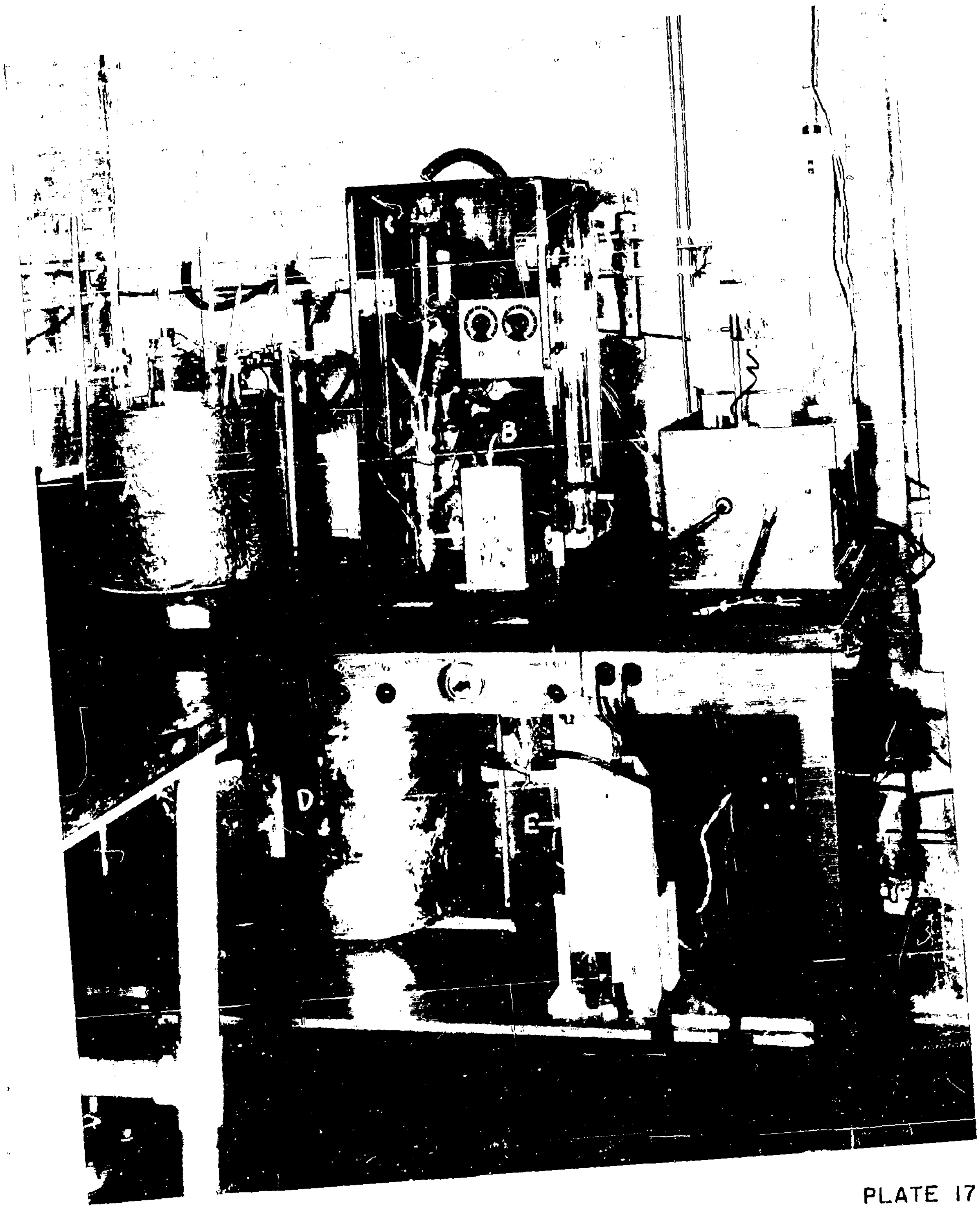
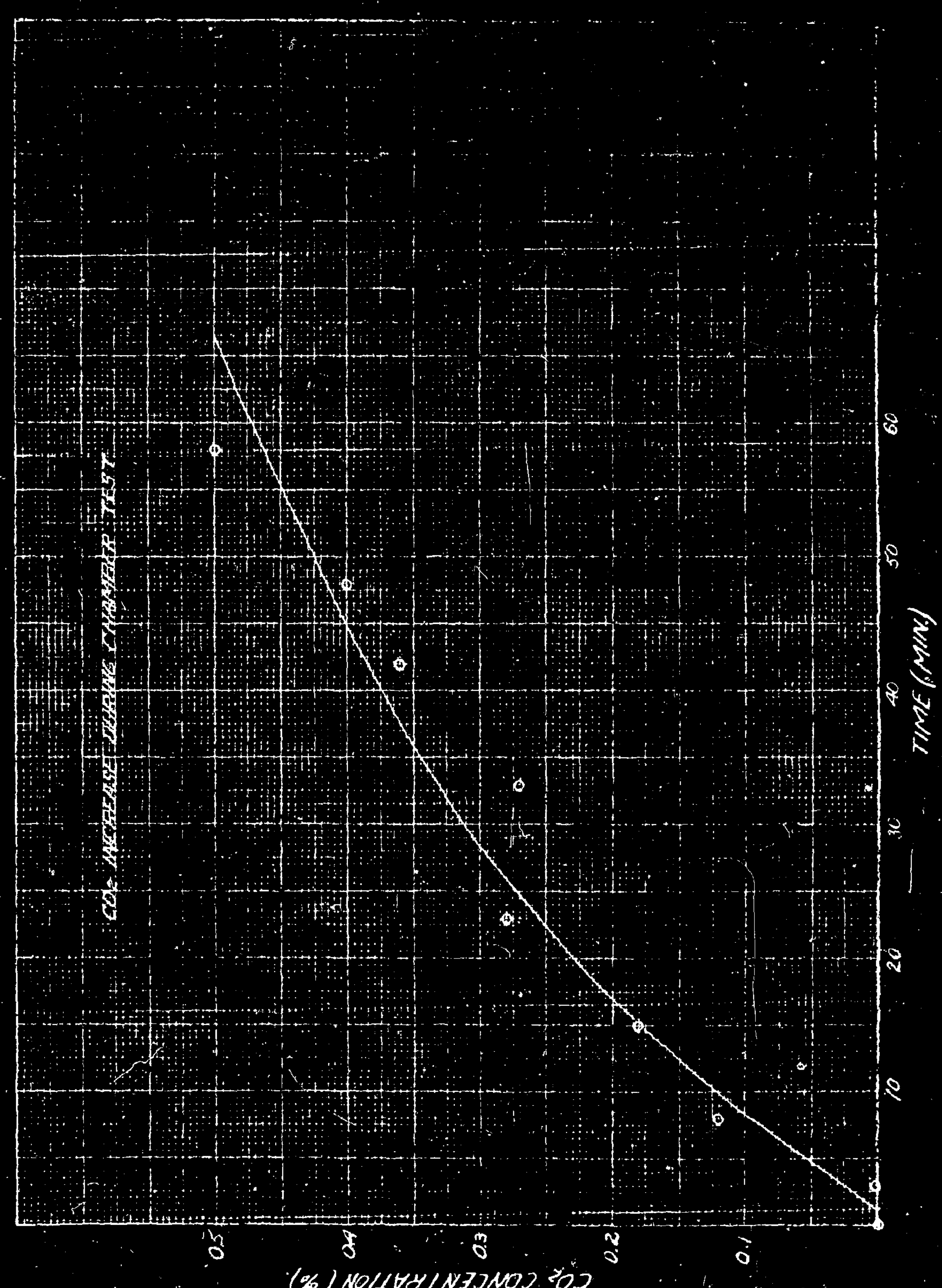


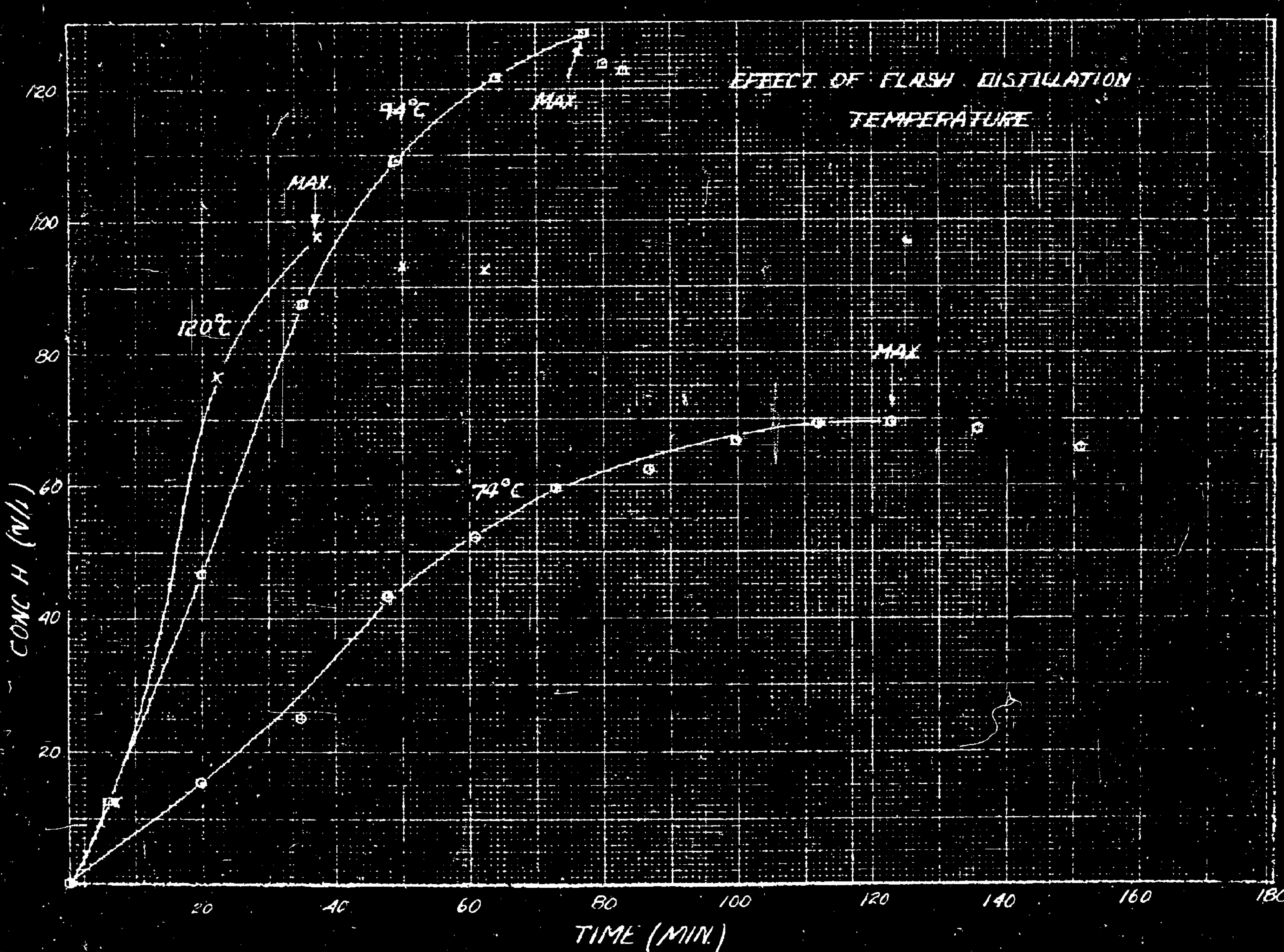
PLATE 17

CONFIDENTIAL



CO_2 INCREASE DURING CHAMBER TEST
TIME (MIN.)
10
20
30
40
50
60
CO_2 CONCENTRATION (%)
0.1
0.2
0.3
0.4
0.5

PLATE 18



EFFECT OF FLASH DISTILLATION
TEMPERATURE
74°C
MAX.
120°C
MAX.
74°C
MAX.
CONC H (1/N)
0
20
40
60
80
100
120
20
40
60
80
100
120
140
160
180
TIME (MIN.)

PLATE 19

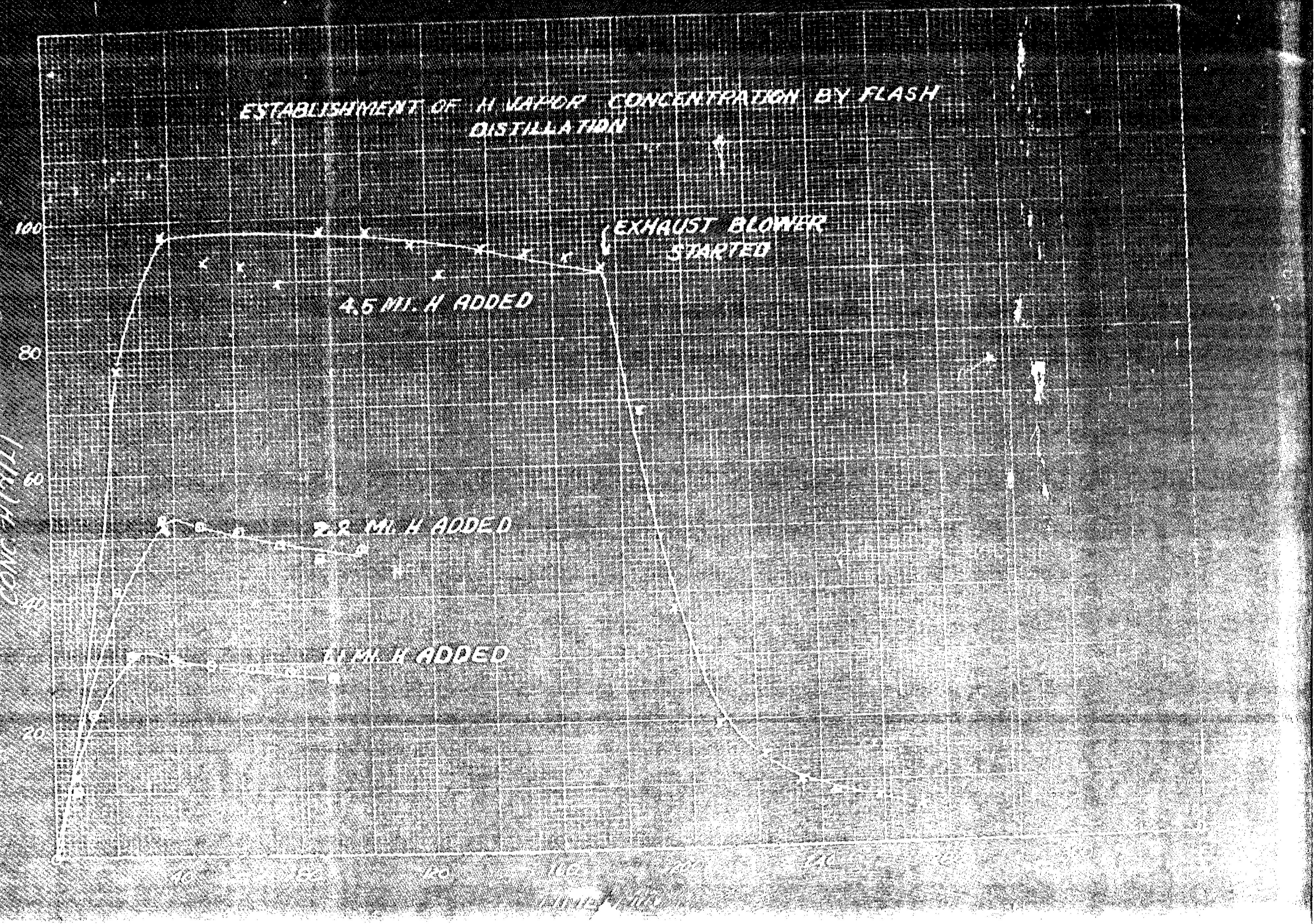

ESTABLISHMENT OF H VAPOR CONCENTRATION BY FLASH DISTILLATION
EXHAUST BLOWER STARTED
4.5 Ml. H ADDED
2.2 Ml. H ADDED
1.1 Ml. H ADDED
100
80
60
40
20
40
80
120
160
200
240
280

PLATE 20

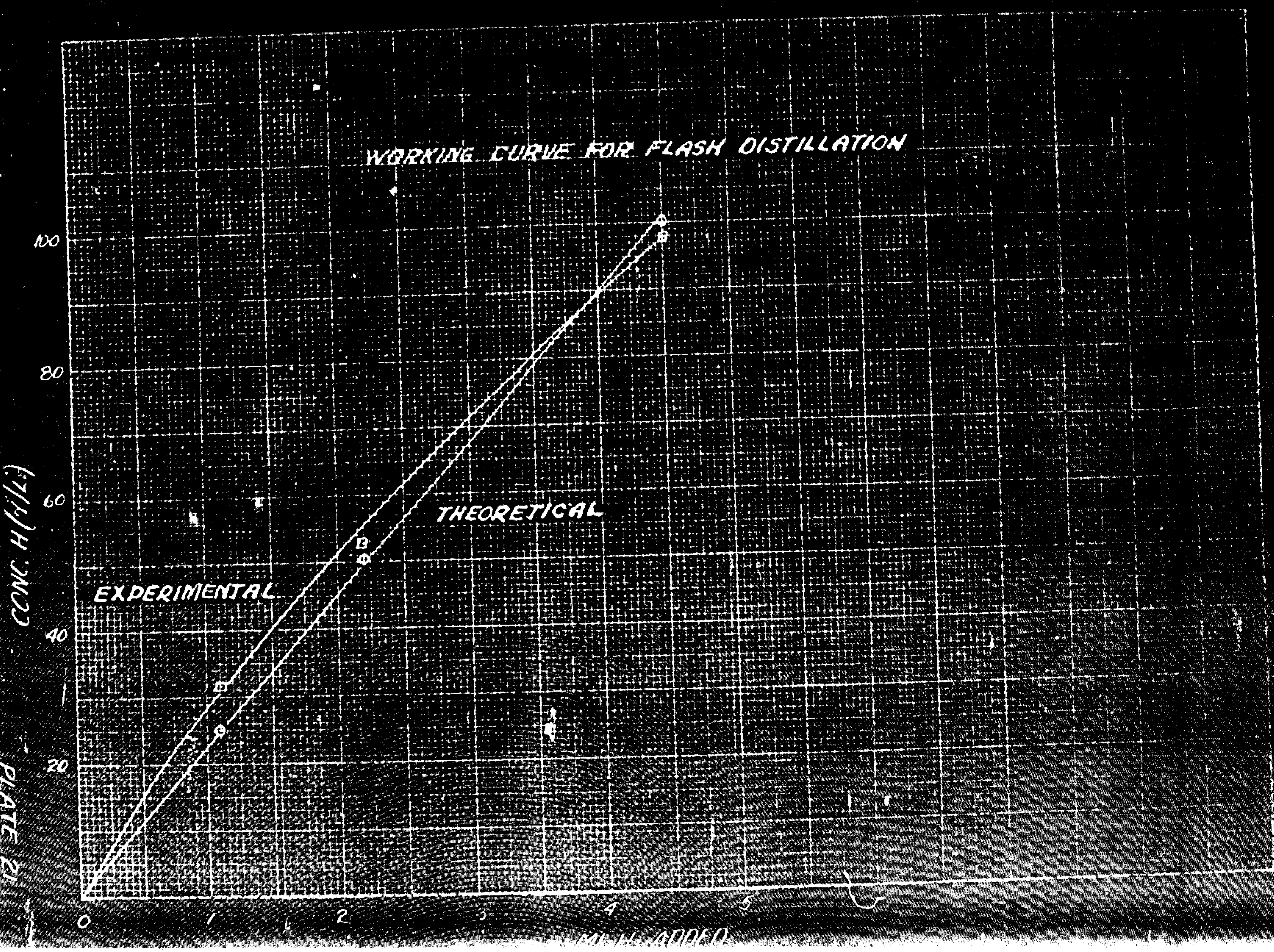

WORKING CURVE FOR FLASH DISTILLATION
THEORETICAL
EXPERIMENTAL
100
80
60
40
20
0
1
2
3
4
5

PLATE 21

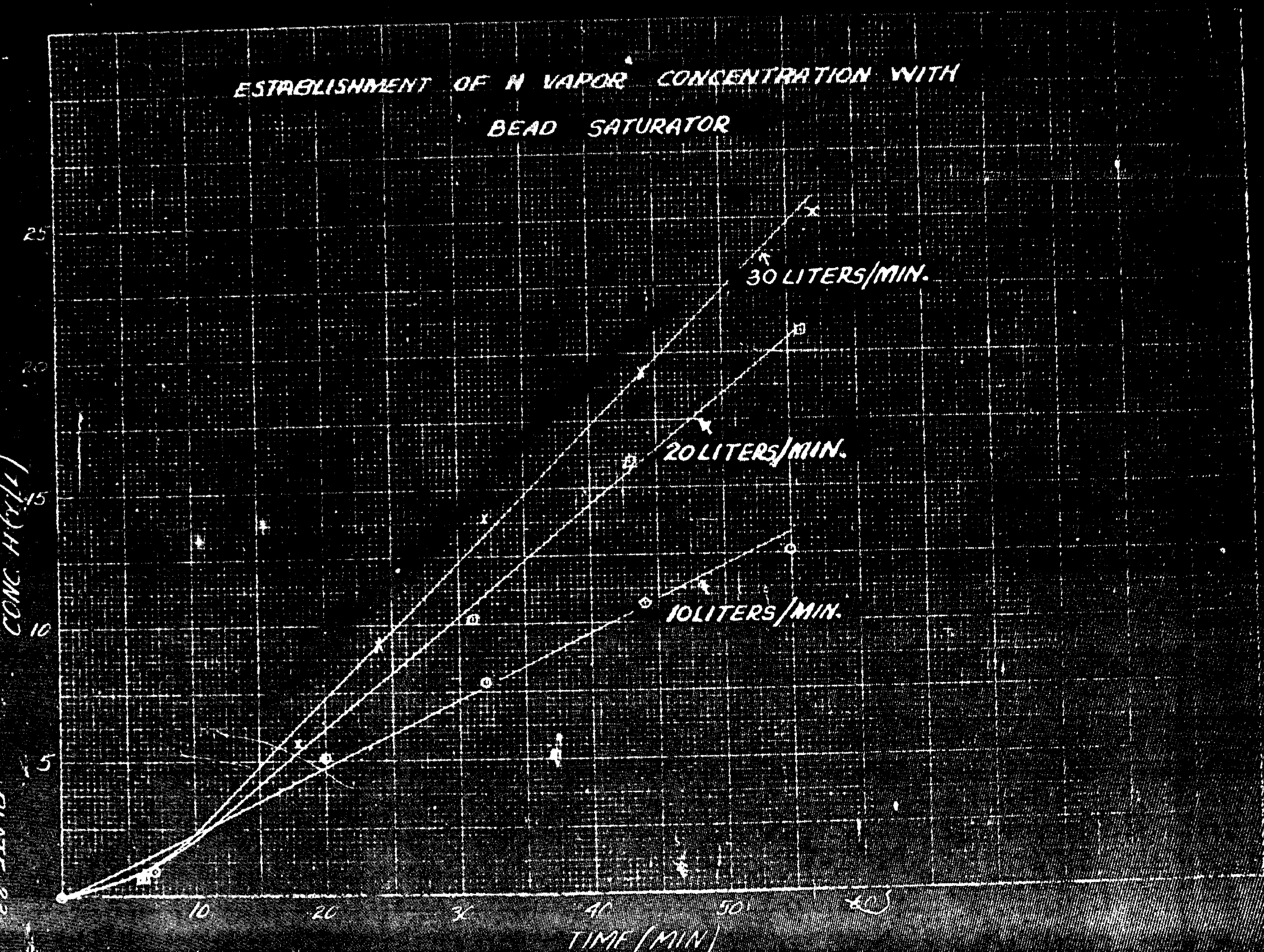

ESTABLISHMENT OF N VAPOR CONCENTRATION WITH
BEAD SATURATOR
30 LITERS/MIN.
20 LITERS/MIN.
10 LITERS/MIN.
CONC
5
10
15
20
25
10
20
30
40
50
TIME (MIN)

PLATE 22

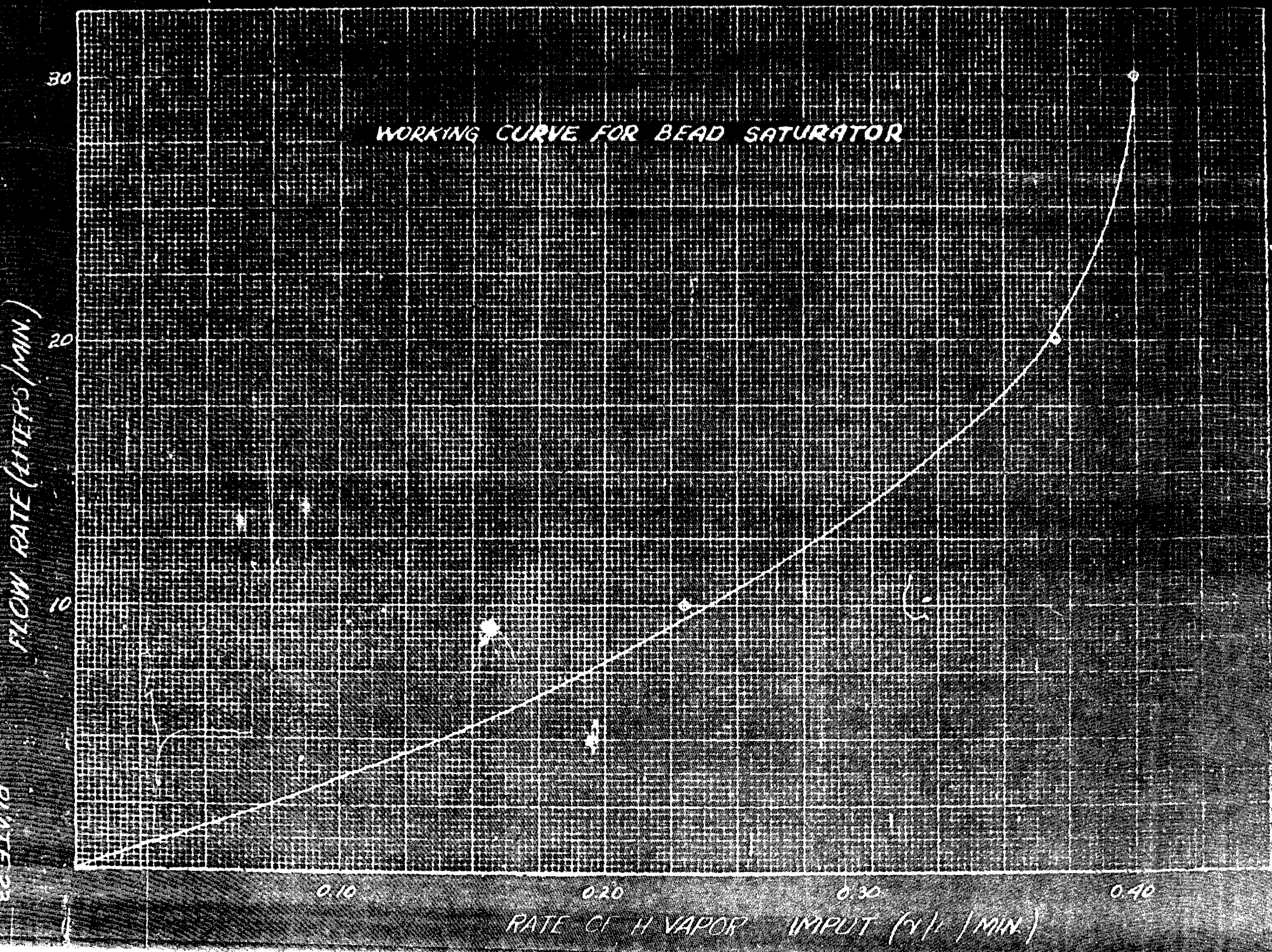
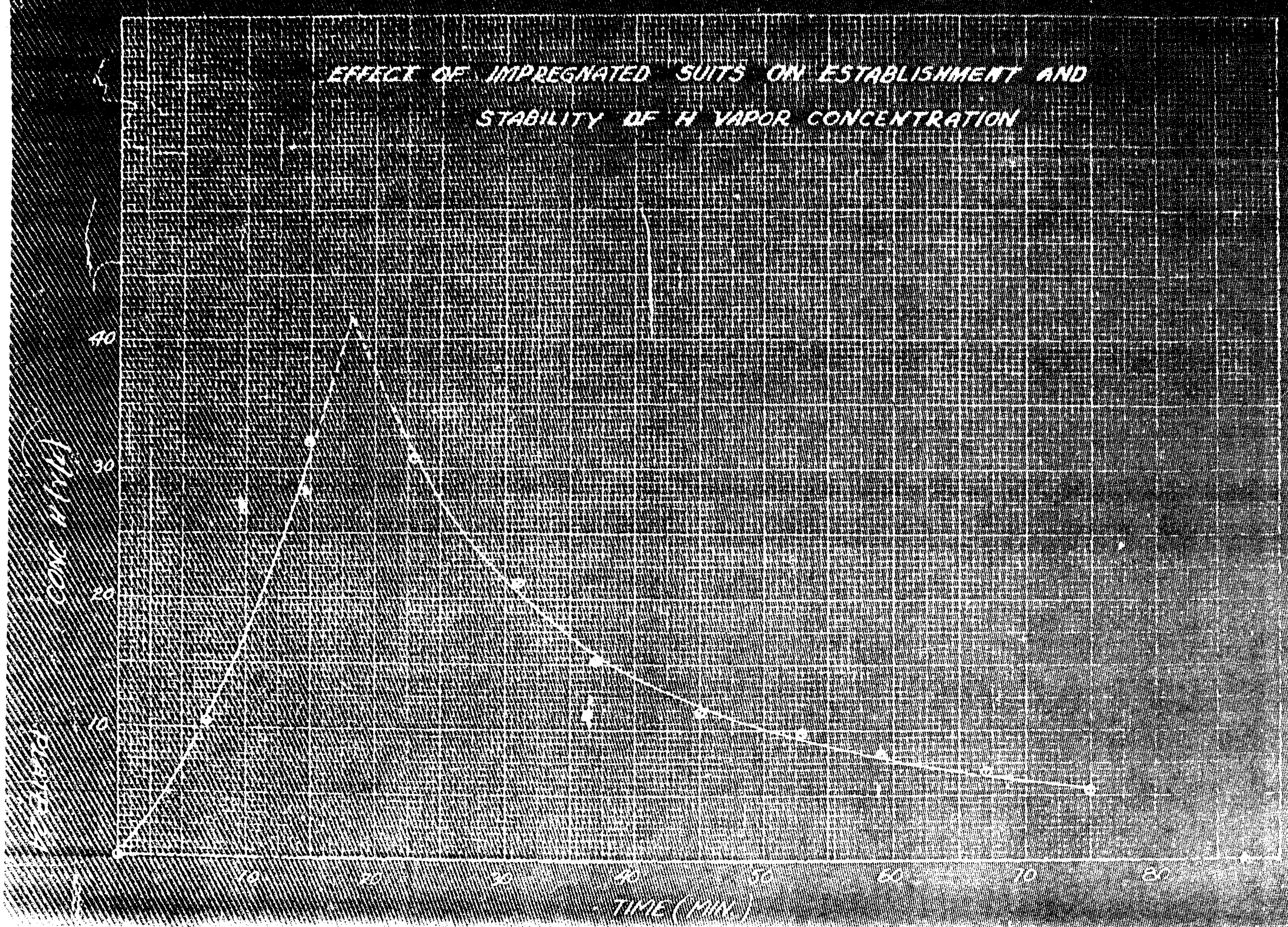

WORKING CURVE FOR BEAD SATURATOR
30
20
10
FLOW RATE (LITERS/MIN.)
0.10
0.20
0.30
0.40
RATE OF H VAPOR INPUT

PLATE 23


EFFECT OF IMPREGNATED SUITS ON ESTABLISHMENT AND
STABILITY OF H VAPOR CONCENTRATION
40
30
20
10
CONC H (M/L)
10
20
30
40
50
60
70
80
TIME (MIN.)
PLATE

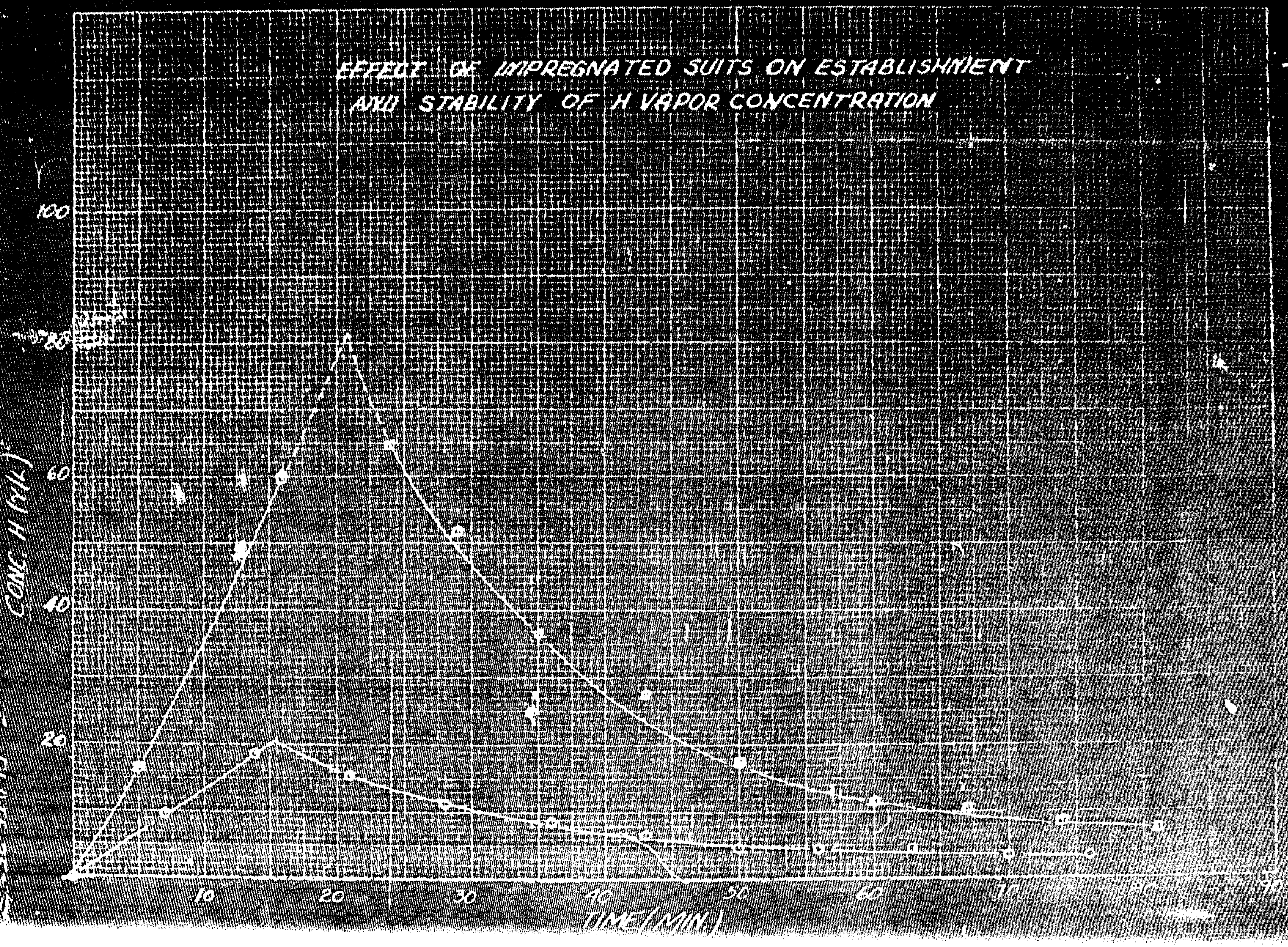

EFFECT OF IMPREGNATED SUITS ON ESTABLISHMENT
AND STABILITY OF H VAPOR CONCENTRATION
CONC. H (γ/L)
100
80
60
40
20
10
20
30
40
50
60
70
80
90
TIME (MIN.)

PLATE 25

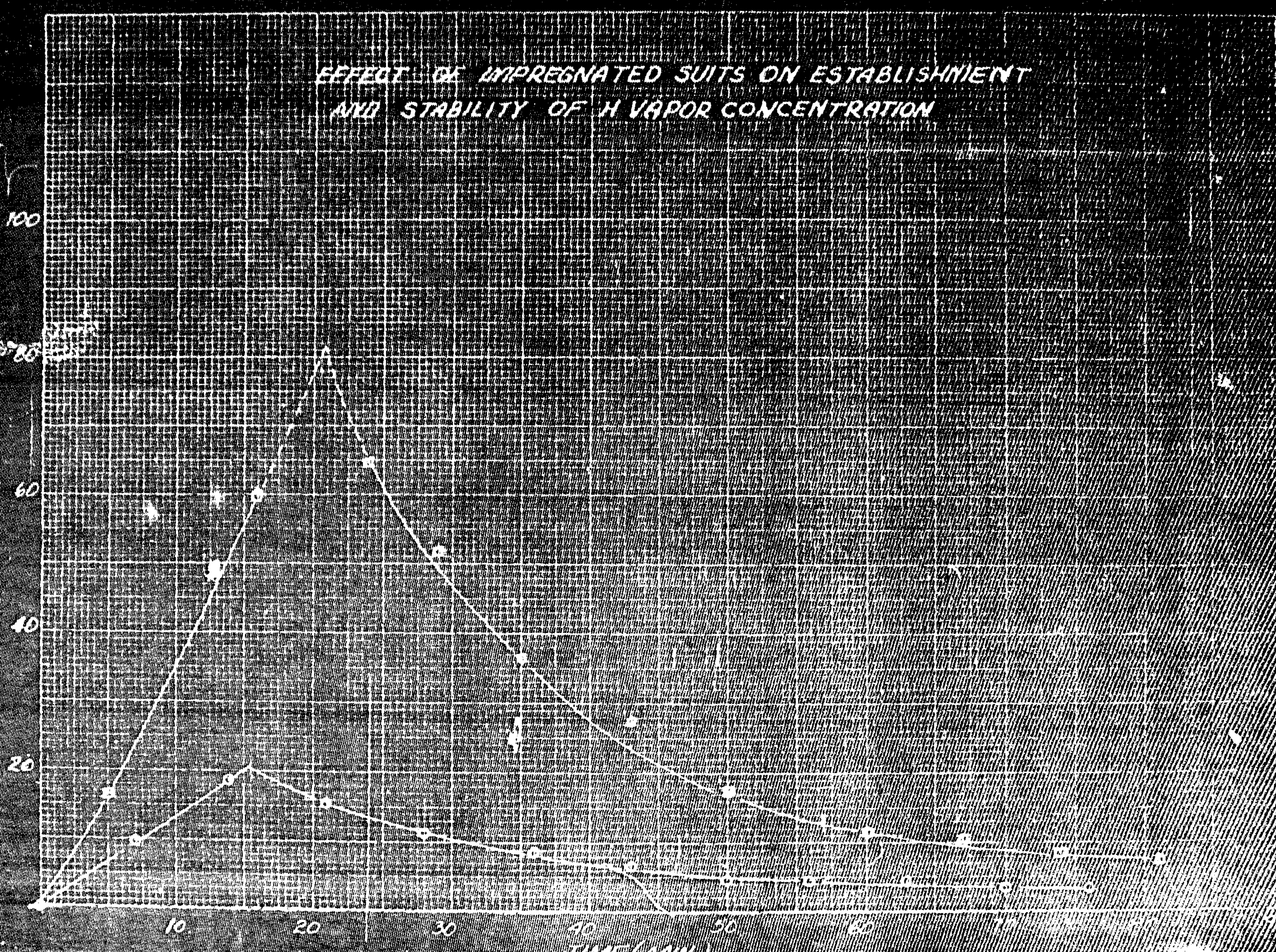
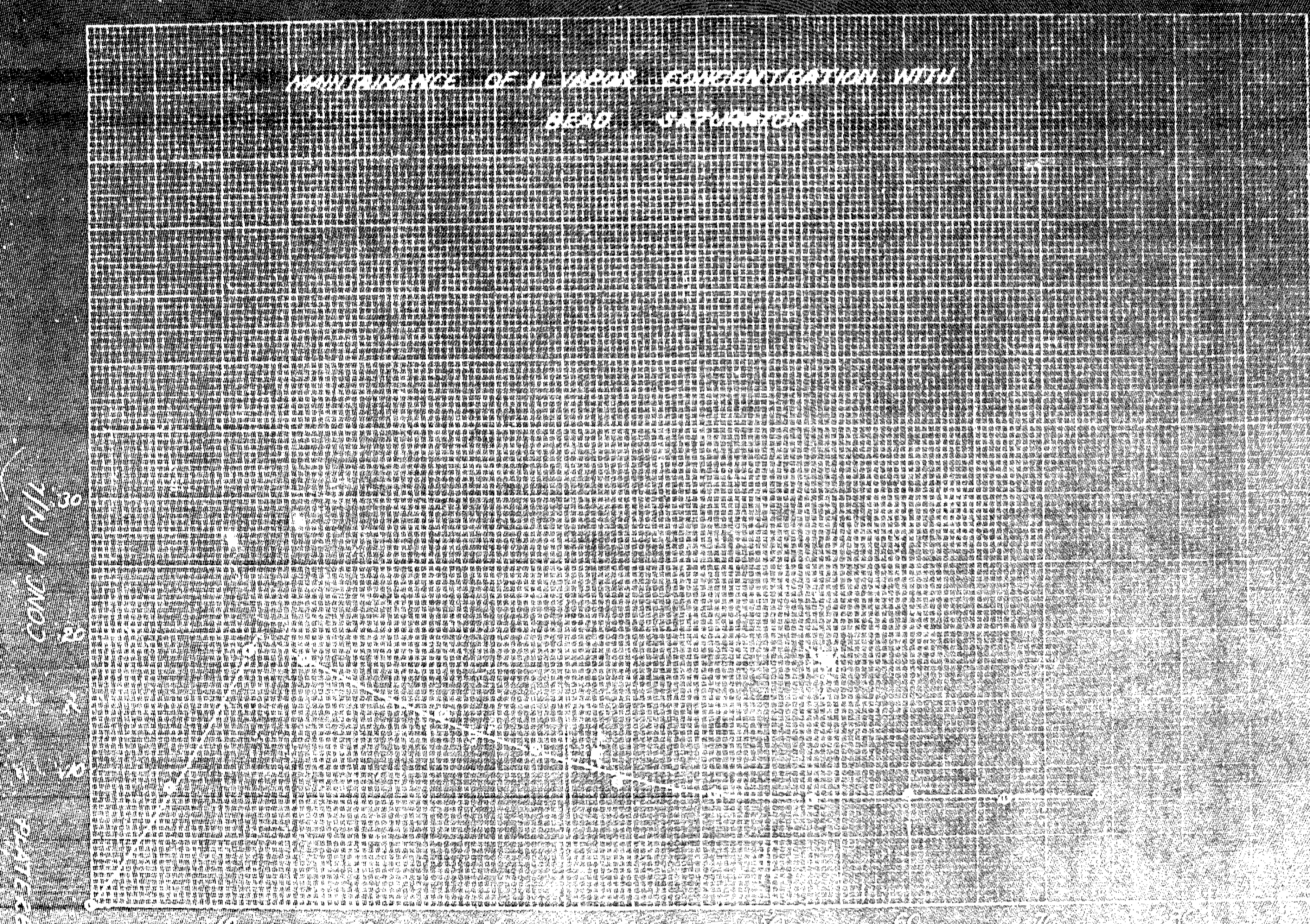

EFFECT OF IMPREGNATED SUITS ON ESTABLISHMENT
AND STABILITY OF H VAPOR CONCENTRATION
CONC. H (γ/L)
100
80
60
40
20
10
20
30
40
50
60
TIME (MIN.)

PLATE 25



MAINTAINANCE OF H VAPOR CONCENTRATION WITH
BEAD SATURATOR
CONC H (γ/L)
30
20
10
10
20
30
40
50
60
70
80
TIME (MIN)

PLATE 26

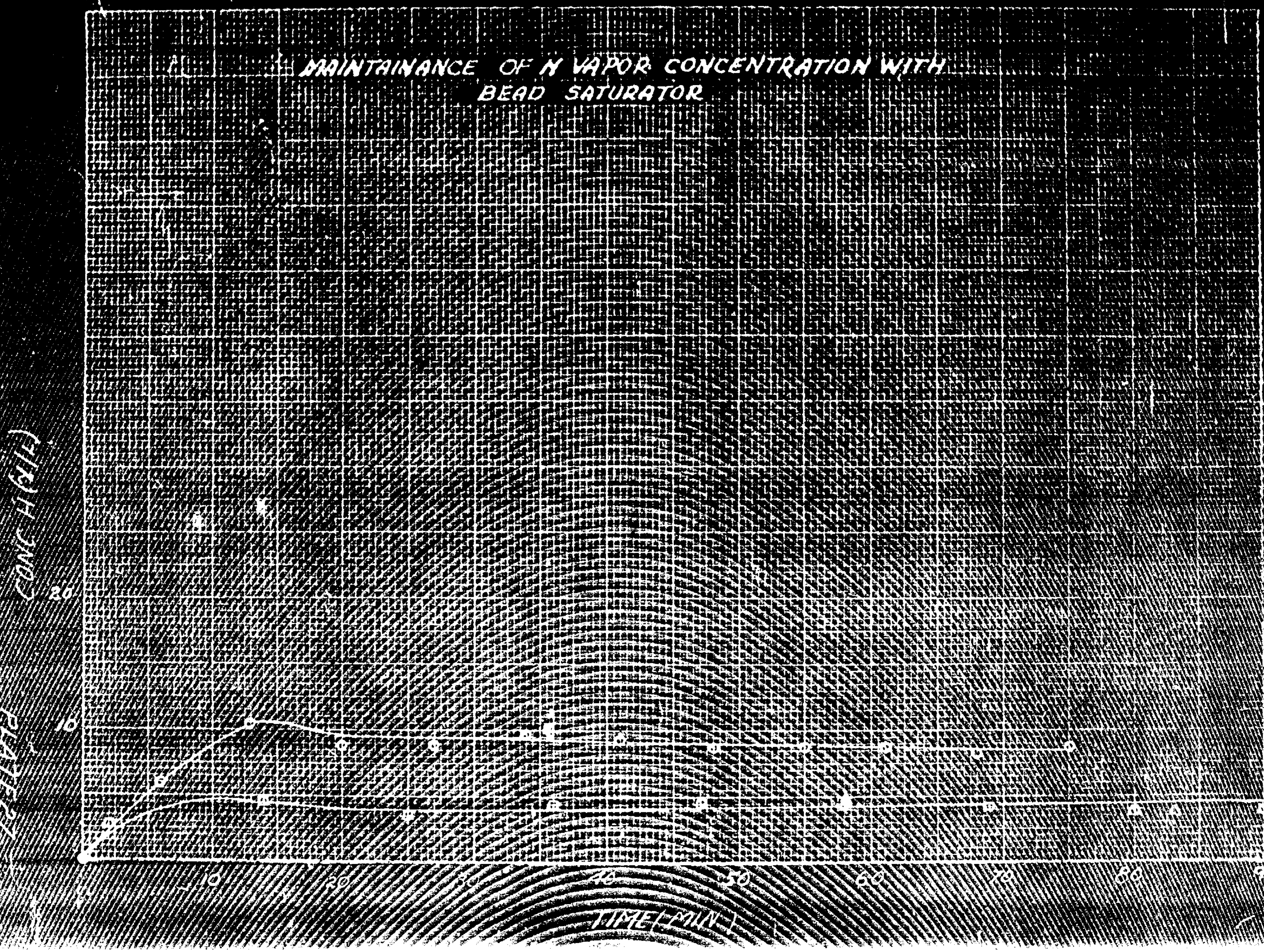
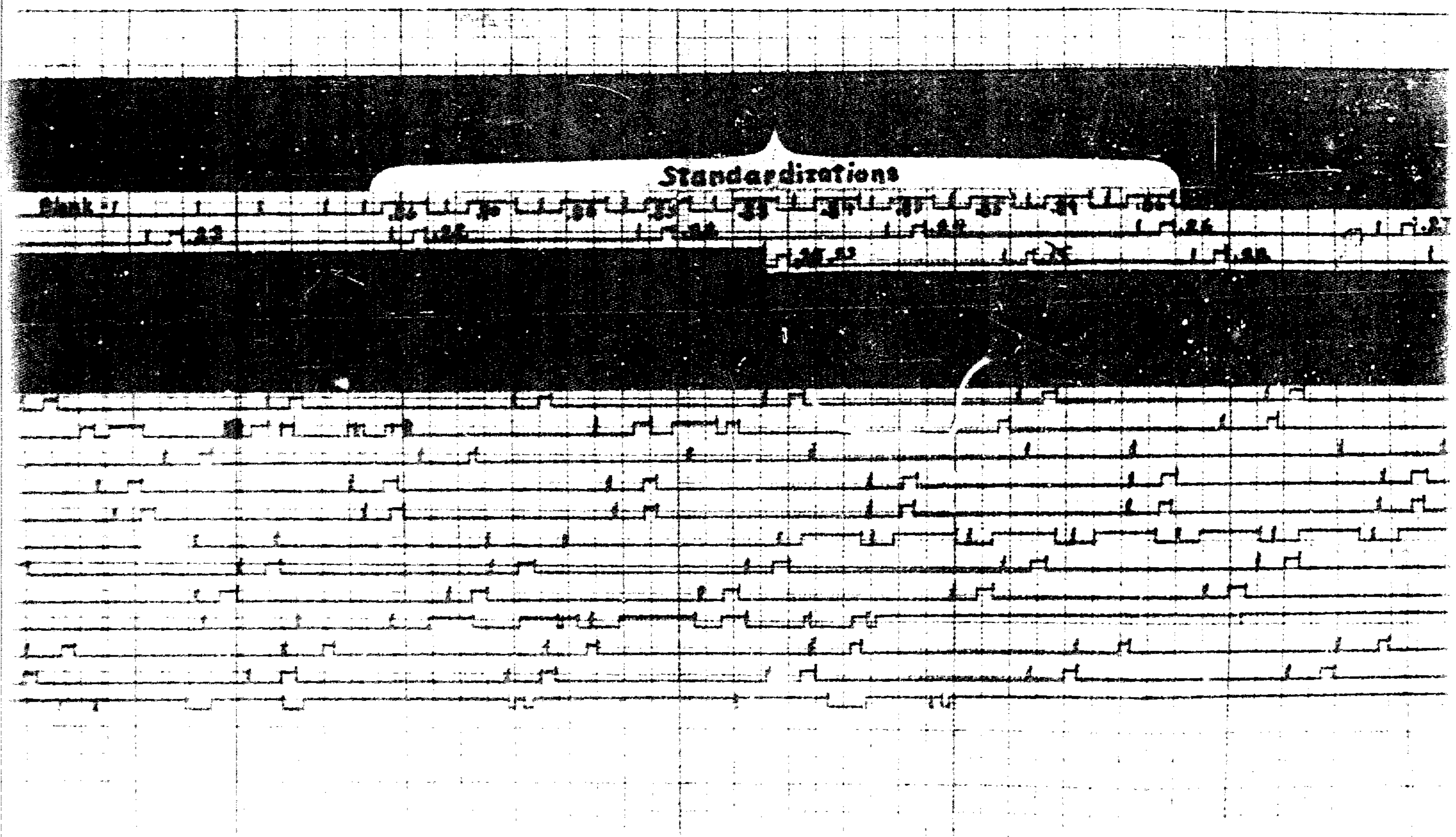

MAINTAINANCE OF H VAPOR CONCENTRATION WITH
BEAD SATURATOR
CONC H (M/L)
20
10
10
20
30
40
50
60
70
80
TIME (MIN)

PLATE 21


Standardizations

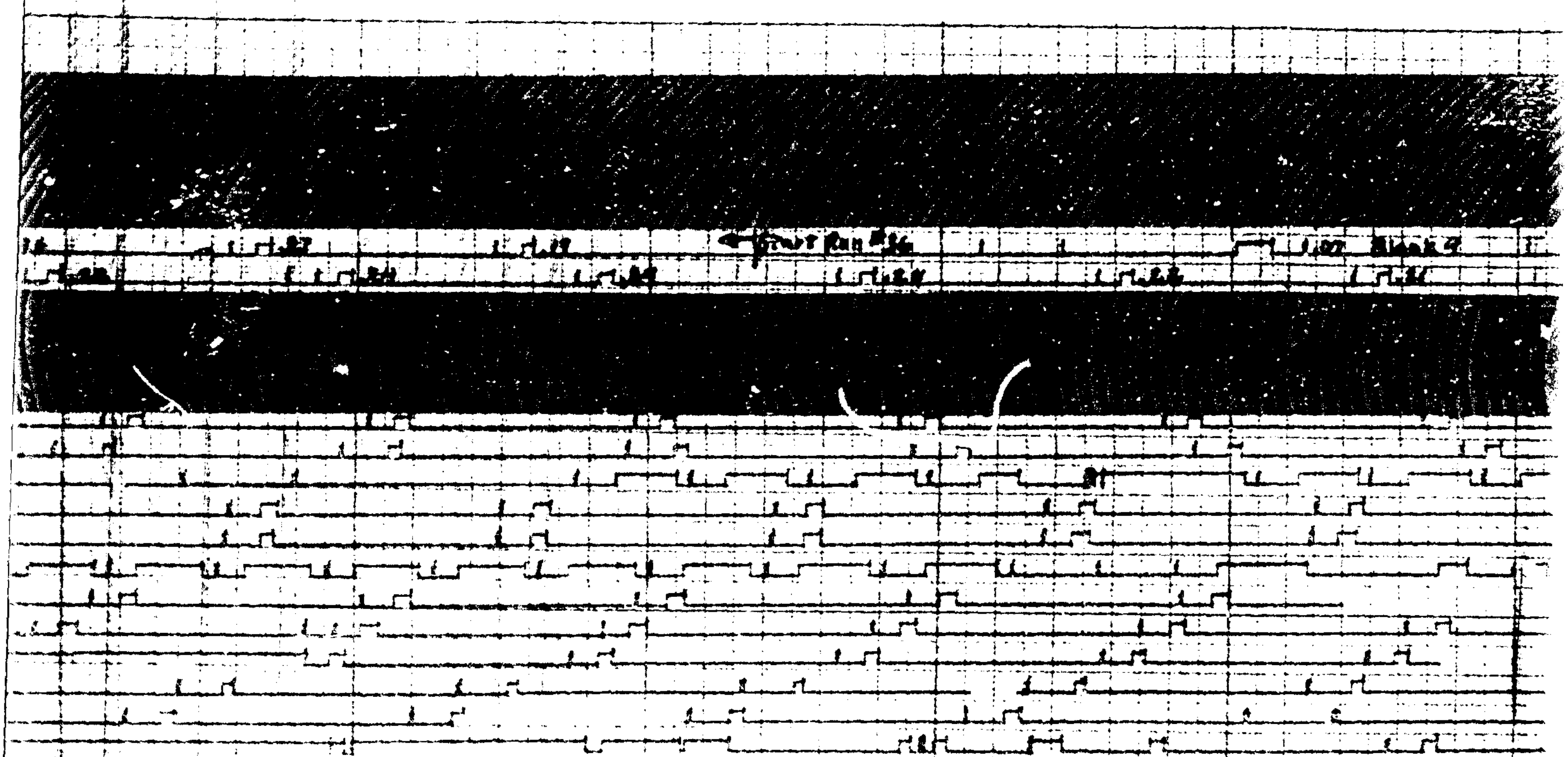
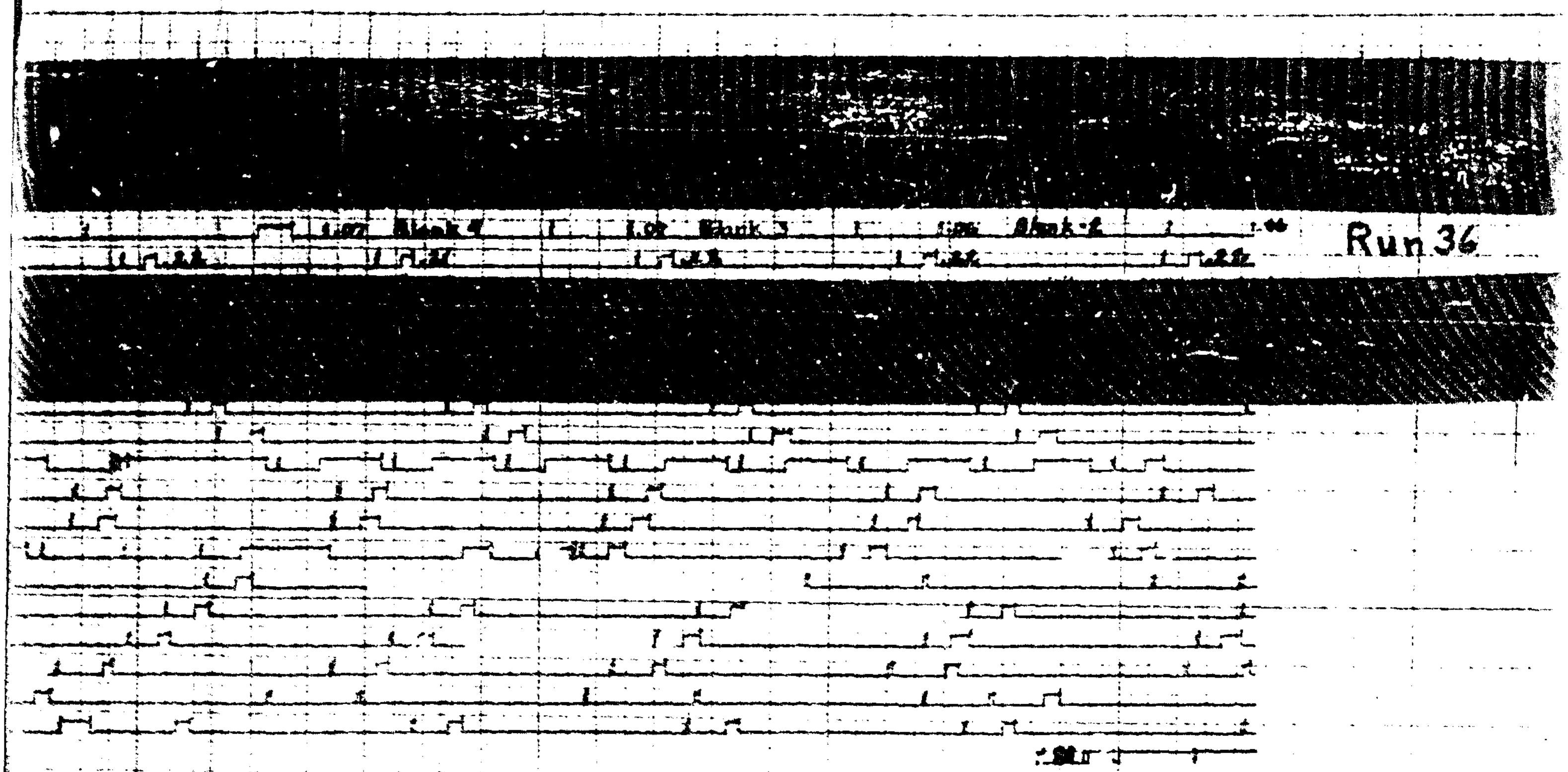


Plate 28



Chamber Runs 35-45

K Williams 10-23-43

TEMPERATURE-HUMIDITY RECORD FOR RUN 36

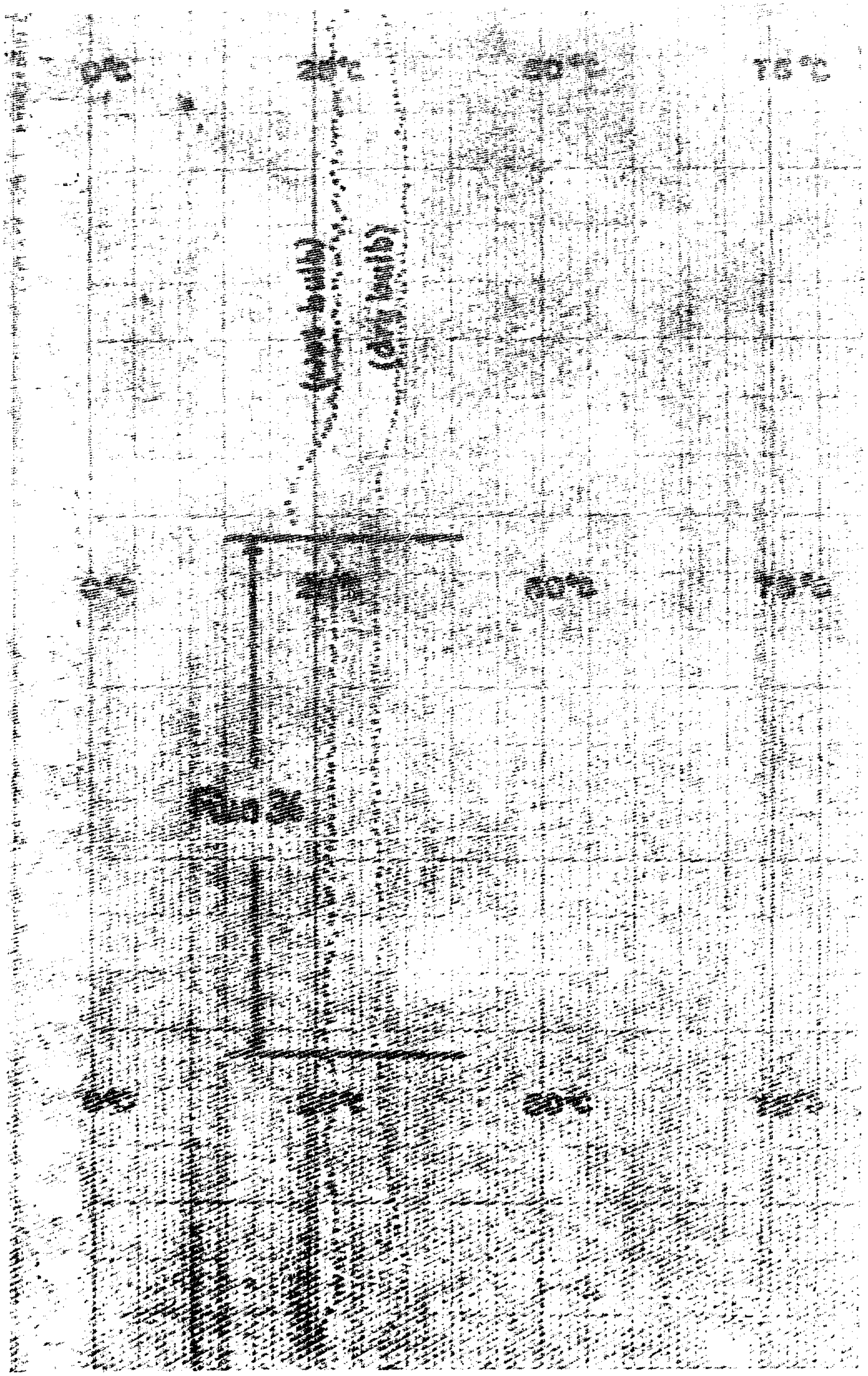


PLATE 29

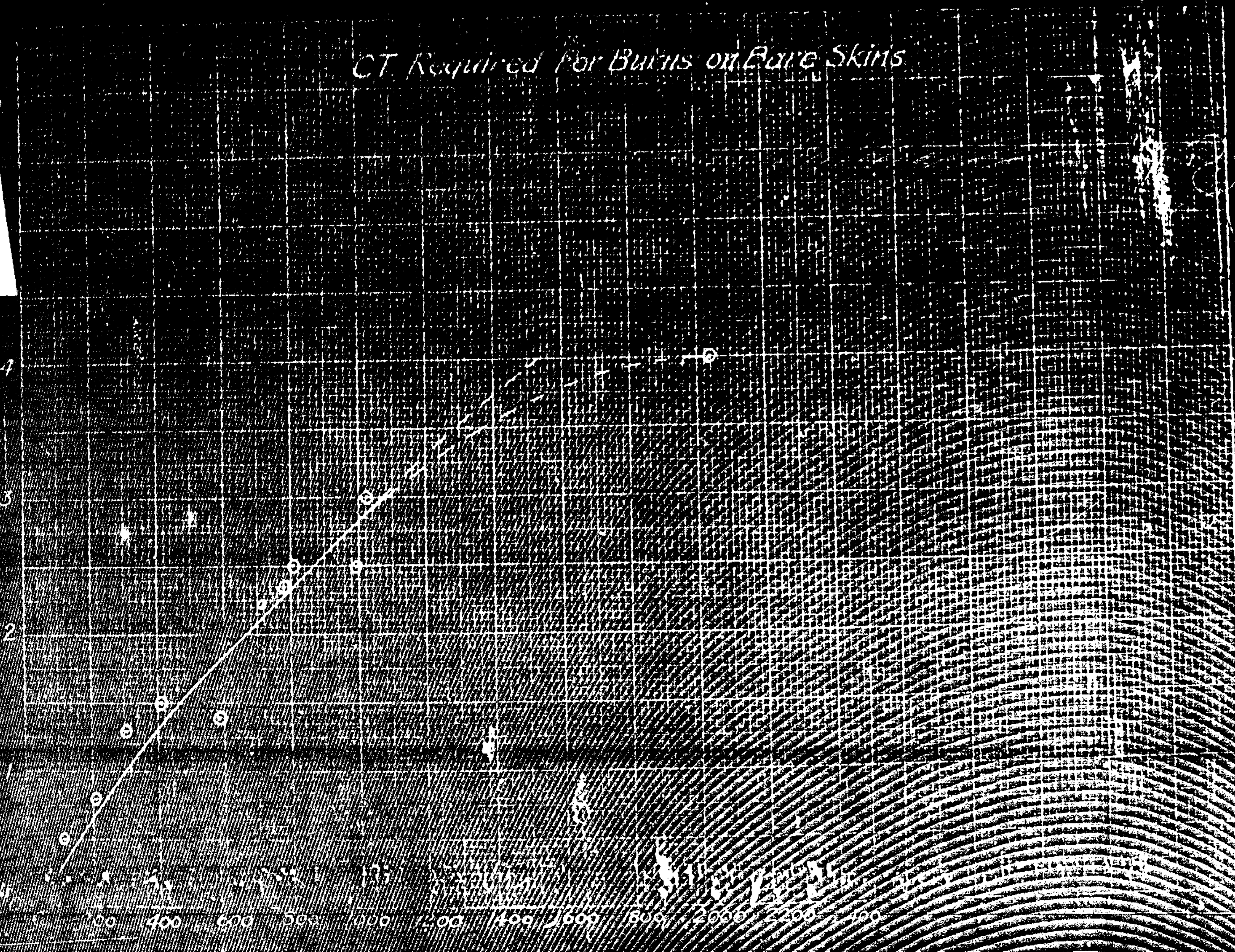

CT Required For Burns on Bare Skins
Burn Severity
1
2
3
4
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

PLATE 30

UNCLASSIFIED

UNCLASSIFIED